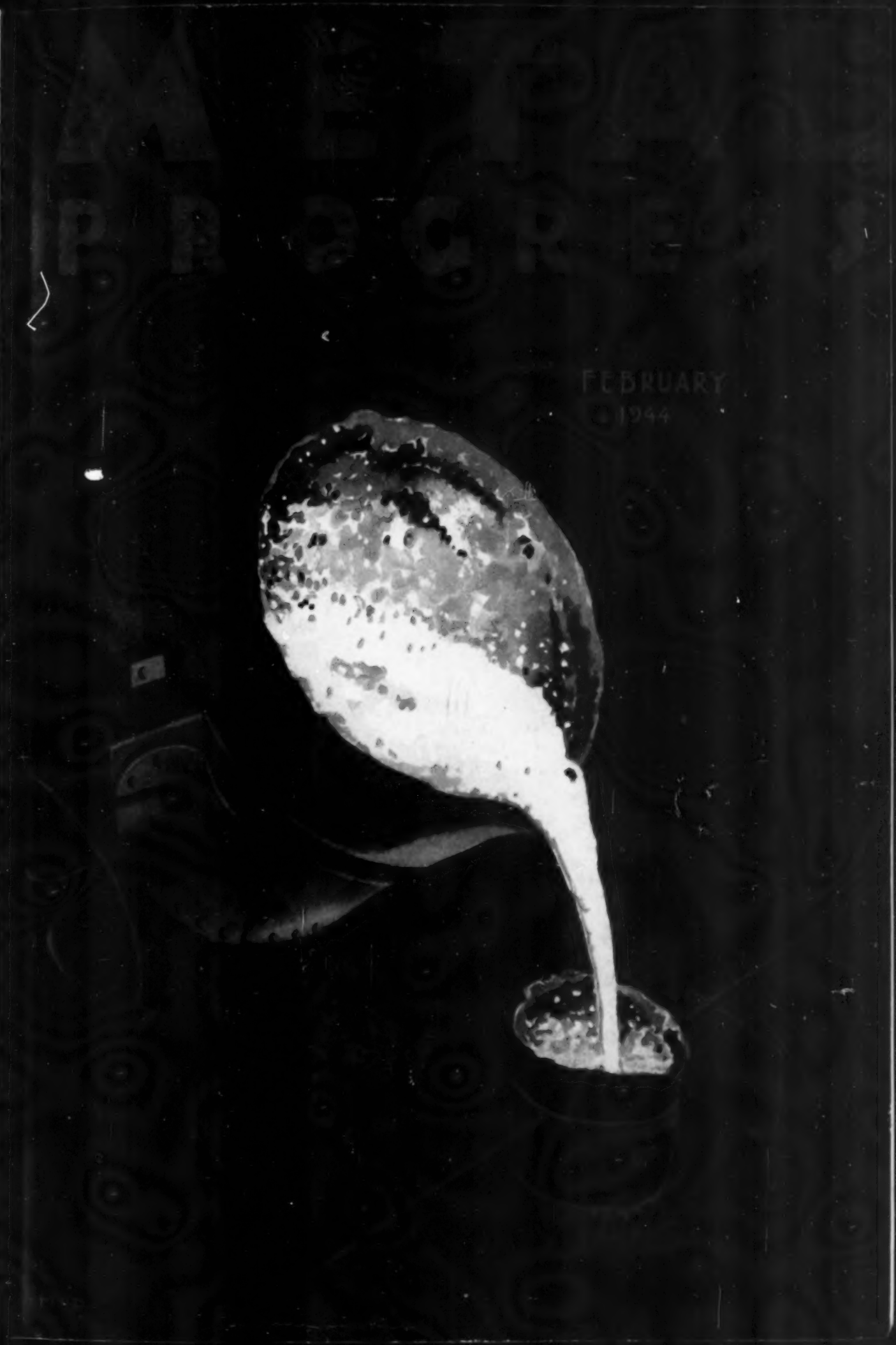
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Vol. 45 *February, 1944* *No. 2*

Table of Contents

Cartridge Brass — Effects of Chemical Composition, by L. E. Gibbs . . 265

Improving X-Ray Radiographs by Filtering Out Secondary Radiation, by Robert Taylor 270

The Determination of Equilibrium Diagrams by X-Ray Methods . . 272
Abstracted from round table discussion, *Journal*, Institute of Metals, London, 1943, Vol. 69, Publication 931

Critical Points, by the Editor 273
Peace is our prize
Victories by researchers and technologists
Weldments and metals for diesel locomotives
Fruits of 25 years' study of aluminum
Half the labor saved

Steel Plate Clad With Cupro-Nickel Sheet, by Joseph V. Kielb . . 276

Roy Arthur Hunt, 1942 Recipient, ASM Medal for the Advancement of Research 280

Consumer Control of Quality by Inspection

Separating Important From Unimportant Inspection Operations, by Arthur W. F. Green 282

The Personal Equation in Inspection, by John W. W. Sullivan . . 284

Acceptance Control — Not How Much Inspection, but How Good, by L. E. Ekholm 286

Precision Measurements, by John A. Harrington 288

Control Charts, by C. S. Gotwals 290

Acceptance Inspection of Ammunition, by H. R. Bellinson 292

Identification of Inclusions in Iron and Steel; Data Sheet . . 294-B

Bits and Pieces; Metallurgicus' Own Department
Cycle Annealing, by Metallurgicus 295
Spot Tests for Non-Ferrous Alloys, by Sidney Lenhoff, Robert J. Sherman, Philip A. Savage, J. T. Evans, Jr. 296
To Distinguish Stainless From Inconel, by Member of R.A.F. . . . 297
Polishing Soft Steel (Cartridge Cases), by Robert F. Nelson . . . 297
Rapid Hardening of Sprockets, by S. H. Covert 297

Weldability of Steel, by Martin Seyt 298

Personal Items 306, 308, 310

Substitute Alloy for Bronze Worm Gear, by Non-Ferrous Technical Committee, Institute of British Foundrymen . . . 312
Abstracted from *The Metal Industry*, July 23, 1943, p. 50 e.s.

New Products 330, 332, 334, 336

What's New in Manufacturers' Literature . . . . . 362 e.s.

Index to Advertisers 404

Editor
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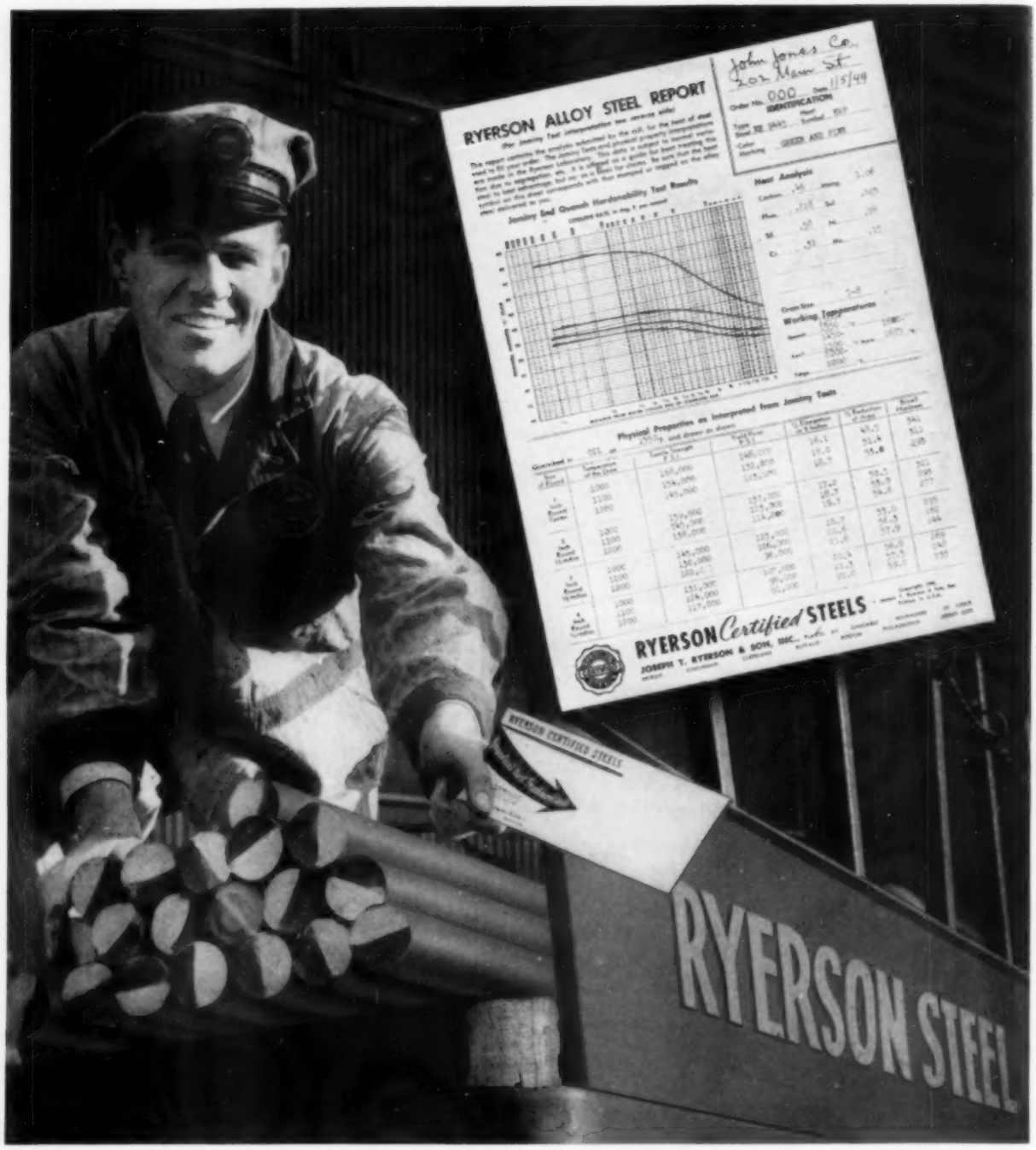

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This, the fourth of a series, carries the discussion of cartridge brass back into some of the problems of the brass mill — of principal interest to consumers for its emphasis on the desirability of adequate scrap segregation and guarding it from careless contamination

Cartridge Brass— Effects of Chemical Composition

Up to now the various discussions on cartridge brass printed in *Metal Progress* have dealt only with the physical properties of the alloy, with the assumption that chemical composition would not affect the cold working and annealing relationships. As far as commercial material is concerned this assumption is substantially correct, since mill control systems, specification and processing requirements tie down the chemical variations to close limits. It would be only an inadvertent shipment of off-analysis material which would upset the properties shown in the previous articles. It is the purpose of this installment to show the control of elements necessary in the brass mill and the reasons therefor, as well as to indicate the advantage of close control of scrap in the consumer's plant.

Regarding the consumer's problem first: Any brass mill must use, for economic reasons if no other, either scrap of its own making, or purchased from its customers. In some alloys, metallurgical reasons may prevent such use, but it is not true with cartridge brass. Because of this need for scrap, it necessarily follows that its analysis must be accurately known, along with impurity limits, if specification and other requirements are to be met. Brass mills buy their scrap with this need in mind, with regulations on source, type, freedom from oil and impurities, and other considerations. Since the price paid for it will vary ("clean heavy" scrap for instance being the highest and most desirable), it is to the advantage of any consumer to keep different analyses separated within his plant, free from steel scrap, oil, and dirt, unless the monetary return is so small as to eat up all the cost of segregation and handling. Mixed scrap and scrap of unknown composition is usually considered fit only for the refinery, where it is smelted into pure copper. Such scrap has a limited market value; an examination of published schedules will show this.

The brass mill exercises close control of impurities such as iron or lead, as well as of the main metals copper and zinc, not only because cartridge specifications require it, but also because some impurities prevent successful manufacture, while others hinder it to a degree which greatly reduces efficiency. From the consumer's standpoint, there are few impurities which would cause trouble and which would not, at the same time, prove objectionable to the brass mill. Therefore, means for scrap segregation and melting-room control of scrap and virgin materials are a regular part of the operations of brass making. Systems are established to segregate own mill scrap at point of origin for subsequent return to scrap storage, which systems are

By L. E. Gibbs
Technical Advisor, Rome N. Y. Division
Revere Copper and Brass Incorporated

tied in closely to identification procedures regularly employed during production of material destined for customers' use. Considering the hundreds of alloys and forms normally made in one plant, some such system is highly necessary. Melting charges may be controlled by the chief chemist or similar responsible person, who actually designates the amounts of various grades of scrap to be supplied to each furnace from the weigh room. Charges will be made up according to the scrap available, together with some virgin or mill copper scrap, if necessary, and zinc of the correct grade. At the same time the chief chemist will probably have control of finished billets, cakes, extrusion blooms, and other heavy intermediate products, until his analyses are completed, at which time he will either send them to the fabricating mill — or reject, if off-analysis.

A.S.T.M. Specification B6-37 for Slab Zinc

Grade	Lead, max.	Iron, max.	Cadmium max.	Sum of Lead, Iron, Cadmium, max.
Special high grade	0.007%	0.005%	0.005%	0.010%
High grade	0.07	0.02	0.07	0.10
Intermediate	0.20	0.03	0.5	0.50
Brass special	0.60	0.03	0.5	1.00
Selected	0.80	0.04	0.75	1.25
Prime Western	1.60	0.08	...	...

Control of raw materials is also necessary, mostly on zinc, but also on special alloys for addition agents to materials other than cartridge brass. Zinc is purchased by "grade", as established in Specification B6-37 of the American Society for Testing Materials. Analyses are tabulated alongside for reference, and should be kept in mind in any discussion concerning the effects of lead, iron and cadmium. The grade of zinc which will be used depends on the specification limits on impurities, how much dilution there will be by scrap or copper addition, and what method of processing the brass mill intends to employ.

As far as the fabricating methods in the brass mill are concerned there are four of major interest: *(a)* Casting into shape required for subsequent processing, *(b)* hot working or rolling for cartridge case strip, *(c)* cold working or cold rolling, and *(d)* annealing. There are impurities to upset normal procedures for each of these processes, some more than others. However, the most common or serious effects are noticed in the hot or cold fabrication and annealing and are due to a relatively few common contaminants.

As an example, the newer brass mills rely heavily on hot rolling for "breaking down" castings (ingots or slabs) for subsequent cold finishing and annealing. The presence of a small amount of lead produces hot shortness — that is, at the worst the casting crumbles, or at the least edge cracks appear when roll pressure is applied. Antimony tends to cold shortness, one typical effect being lengthwise splitting down the middle.

The most frequent effect, considering the number of elements behaving similarly, is suppression of grain growth. Phosphorus, iron, chromium, nickel, to name a few, are quite powerful in this regard when present even in small amounts. Grain growth suppression is important from the standpoint of annealing schedules, which are established to produce certain grain sizes. The importance of correlation of cold working and annealing has been accented in previous articles in this series, but impurities which throw off balance the normal relationships are just as bad as no correlation at all. In actual practice, for example, high iron will produce a grain size smaller than expected with the cold working plus annealing time and temperature ordinarily in vogue. (In passing it might be said that for certain uses of electrolytic copper, the elements silver and cadmium are deliberately added to increase the annealing temperature — that is, to suppress grain growth deliberately.)

As for specific effects: Changes in copper content in cartridge brass are not serious as far as fabrication is concerned, except in very severe cupping jobs, wherein copper over 70% seems to eliminate edge cracking. The usually specified range of 68.5 to 71.5% copper (31.5 to 28.5% zinc) is not within a border-line area in the equilibrium diagram (see Fig. 21★). There are commercial alloys either side of the range which are regularly used for hot and cold working, although in last June's installment we have shown optimum properties occur at the 70-30 composition. Further examination of the equilibrium diagram will show, however, that this does not always obtain. As 65% copper, 35% zinc is reached there is opportunity for the beta phase to appear and as copper approaches 55% (zinc 45%), more and more beta brass occurs. Beta brass is a fine hot working phase, but very poor for cold forming, becoming brittle when cold worked

★Figures and illustrations in this series of articles are numbered consecutively.

under 20%. The hot working characteristics of beta brass are made good use of in many alloys, either with or without lead, and used for extrusions or forgings. Copper alloys with less than about 55% copper are not commercially useful — they are too brittle.

For metallographic identification, beta constituent appears lemon yellow when etched with standard ammonium hydroxide reagent, or is darkened with ferric chloride reagent. (See Metals Handbook, page 1472, for other identification systems.)

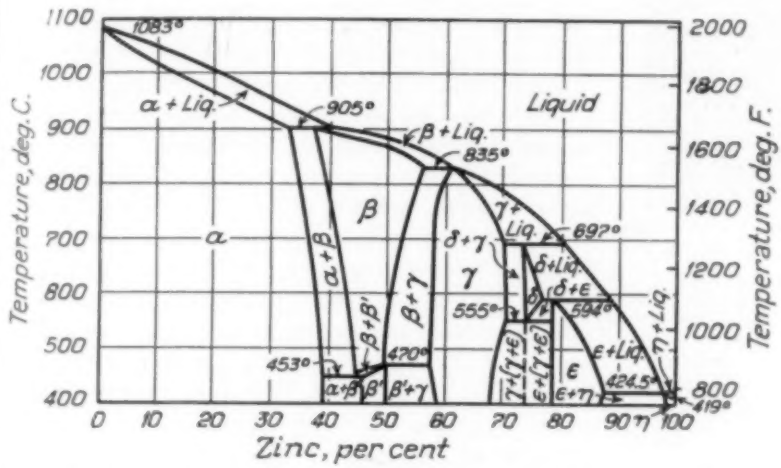

Fig. 21 — Equilibrium or Constitutional Diagram of the Copper-Zinc Alloy System, According to Phillips and Brick

As to the effects of impurities, lead and iron are the most frequently mentioned in specifications as being limited in their allowable maximums. As an example, Army 57-173B (Amendment 7 of Feb. 20, 1941) "Disks-Cartridge Brass" limits 0.070% max. for lead and 0.050% max. for iron. Other specifications are in close conformity. Aside from their undesirable effects — and probably because of them, too — their frequent occurrence in scrap and zinc makes it desirable to check them closely. A large tonnage of leaded brass (free cutting brass rod, forgings, and other shapes) is returned as scrap, and admixture in cartridge brass is relatively simple. Iron, of course, may occur as tramp iron carelessly tossed into a scrap pile or from contamination at some stage of processing near steel fabricating operations. (Magnetic separators are used wherever the scrap form permits.) Other elements may also appear in common every-day production, most of them from platings, such as cadmium, chromium, nickel and tin. Plated scrap is not popular for brass remelting, not only because it tends to cover up the base metal and make identification on color alone that much more difficult, but also because most of these plating metals are powerful in their effects and quantities added are not subject to calculation. It should not be forgotten that no refining takes place in brass melting contrary to steel practice, and the only impurities which are removed to any appreciable degree are those high in their oxidizing power such as calcium, boron, phosphorus and, to a lesser extent, aluminum. Actually all sorts of precautions are taken to prevent oxidation of zinc, such as the use of charcoal blankets on the molten bath.

Common impurities will now be discussed, in alphabetical arrangement.

Aluminum — Scrap aluminum is not a likely source of contamination. As a rule its resale value is high, which prompts proper sorting; also its color is foreign to most brass making establishments. Its possible source, however, is from plants fabricating some aluminum bronzes (5 to 11% Al) and aluminum brass condenser tubing (76% Cu, 2% Al, bal. Zn). It doesn't take much aluminum, however — upwards of a "trace" — to produce a skin characteristic of aluminum when melted, which is quite apparent by a rough surface on castings. There are no adverse effects as far as hot working is concerned or cold working — even with 2%. However, annealing is affected, and aluminum raises the temperature required to produce a given grain size; it is a grain growth restrainer, in other words.

Antimony becomes troublesome when fired cartridge cases are remelted in large quantities, the source being the primer material, apparently, which lodges on the inside of the case after firing. Mixed lots of fired cases have been found to contain about 0.007% antimony. The element has always been of ill repute in brass mills, probably because the effects tend to be cumulative when associated with lead, and influence the hot rolling as well as cold rolling properties. For hot rolling the limit is 0.01 to 0.02%, and for cold rolling 0.10%. Lead present in an amount less than this will accentuate the effects. It is worthy of note, however, that in combination with tin in admiralty metal condenser tubes (71% Cu, 1% Sn, bal. Zn), amounts under 0.10% antimony are added for inhibiting dezincification.

Arsenic most commonly occurs in scrap from admiralty condenser tubing, where it also is used to inhibit dezincification. Arsenical copper may also be a source. It does not adversely affect

Blanking Disks for 155-Mm. Cartridges

hot or cold working when added in commercial amounts (under 0.1% in admiralty and 0.3% in copper) but does affect grain growth. Its presence is denoted by smaller grain sizes than expected, which tends to lower ductility unless annealing temperatures are raised.

Bismuth — As far as the brass mill is concerned, bismuth can probably be classed as the bad boy of them all, and has been anathema as long as it has been recognized for its ill effects. Alloys containing it can be handled in cold working or in annealing if its presence be known. Since it rarely appears, routine checks do not catch it, but processing does. It has been shown that 1% bismuth can be handled by suitable annealing and cold working schedules, or by adding phosphorus. However, without precautions, as little as 0.05% will cause cracking in cold working, and 0.006% is considered by many to be excessive for maximum cold working properties (Army specification 57-173B, maximum tolerance 0.006%). As for hot working, 0.006% is about the maximum tolerance, since it causes hot shortness, and is therefore highly important considering the large amount of hot rolling in making of cartridge brass. At the same time "fire cracking" is also attributed to bismuth — that is to say, the cold metal cracks open when placed in a hot furnace without preheating.

Cadmium — Other than as a plating material, cadmium-copper (1% Cd) is the common commercial source of cadmium in scrap, though it is a relatively minor quantity item. As to its effects, it is not clear exactly what happens. In copper, it increases tensile strength and the annealing temperature but does not radically affect processing procedure. In cartridge brass, some claim that 1% cadium has no adverse effect, but others believe as little as 0.05% may have a bad influence on deep drawing quality. In mill processing, cadmium less than 0.25% promotes fire cracking after cold rolling.

Chromium — Solubility of chromium is limited in brass and (aside from possible chromium plated scrap) this limits the alloys containing it and its importance as a possible contaminant. Apparently no ill effects to working properties accrue when it does dissolve, but it does powerfully affect annealing temperatures, restraining grain growth. Chromium contents of 0.05% produce grain sizes of 0.020 mm. at 550° C. (1022° F.) whereas an alloy with no chromium under similar conditions shows a 0.060-mm. grain size. Iron adds to the grain growth restraint when present with chromium. Not all impurities contribute to this additive effect — for example, silver and arsenic each increase the annealing temperature of copper, but together do not produce an effect greater than one alone.

Iron — There is a certain amount of disagreement concerning the limits of solubility of iron in brass. Regardless of this, some is picked up from scrap contaminated by tramp iron, or it could be obtained from aluminum bronzes or so-called manganese bronzes, both of which contain varying amounts up to about 4.0% iron. As an impurity, iron affects annealing primarily, and some claim in an erratic fashion. Part of the discrepancies might be concerned with the current belief that iron can precipitate from the alloy which, if so, could account for varying degrees of hardness resulting from certain annealing tests. It is not necessary in this discussion to do more than recognize iron as a grain growth restrainer. One set of results shows the following effects on grain size (direct comparison with data in previous installments is not possible because of the differing reductions prior to annealing):

Temperature	Less Than 0.02% Iron	Approx. 0.1% Iron
800° F.	0.030 mm.	less than 0.010 mm.
900° F.	0.040 mm.	less than 0.010 mm.
1000° F.	0.070 mm.	0.020 mm.
1100° F.	0.110 mm.	0.060 mm.

There is also a hardening effect of iron, naturally, since grain growth is suppressed, and which, on annealing curves shown in Fig. 7 of the August 1943 installment in *Metal Progress*, appears generally as an upward bulge in hardness between 1000 and 1200° F. Most specifications limit iron to 0.05% max. to keep the annealing characteristics under control.

Lead, similarly to bismuth, selenium and tellurium, is not soluble in copper or copper alloys. (Metallographically, it appears as small globules or as streaks, the appearance varying according to cross section and lead content.) Its presence in scrap has been mentioned. Reason for its addition is to impart free cutting quality, the chips breaking very readily. In hot or cold working it tends to create a weakened condition. In hot rolling it appears as hot shortness and lead must be kept under 0.01% to successfully roll a brass in the hot mill. (Alloys containing up to 4% lead are hot worked by extrusion processes.) For cold working, the severity of the operation plays a considerable part in the allowable tolerance. Alloys containing as much as 2% lead can be made to take shallow draws — with appropriate anneals and generous radii on tools — or be cold headed to a degree. However, because lead lowers ductility of the alloy, maximum allowance for severe working is 0.07%; the ductility progressively decreases, until at 2% lead only about half the cold reduction of lead-free material can be done in the brass rolling mill. No commercial effects on annealing have been noted.

Nickel — Aside from plating, the main tonnage source is cupro-nickel (70% copper, 30% nickel) as far as scrap goes. There are aluminum bronzes and so-called manganese bronzes which may also contain nickel in relatively small amounts — less than about 5%. In conjunction with ponderable amounts of silicon, and more particularly beryllium, it forms a precipitation hardening compound. Other than this, toughness is imparted with resistance to annealing. As an impurity, nickel acts as a grain growth restrainer; for example, 0.16% nickel produces a grain size of 0.090 mm. for a 1300° F. anneal, whereas no nickel shows 0.120 mm. The effect is less noticeable apparently with lower temperatures, since at 1000° F. both alloys were 0.030 to 0.035 mm. in grain size.

Phosphorus — Practically all copper tubing contains phosphorus, in amounts from 0.015 to 0.040%. The same is true of sheet and plate for welding purposes. These can serve as scrap sources of contaminant. Since phosphorus tends to oxidize readily, there is much less tendency to appear in brasses upon remelting than other elements. Regarding the amounts or tolerances: No adverse effects on working are caused by 0.04% and less phosphorus, but on annealing grain growth is restrained. As an example, annealing a phosphorus-free 70-30 brass at 1050° F. produced grain size of 0.040 mm., but the addition of 0.008% phosphorus decreased the grain size to 0.020 mm. With larger amounts of phosphorus, strength is increased and elongation lowered upon annealing. For example:

Phosphorus Content	Annealing Temperature	Tensile Strength	Elongation in 2 In.
0.04%	750° F.	63,000 psi.	43%
None	750° F.	55,000	50
0.04%	1300° F.	49,000	66
None	1300° F.	45,000	74

Tin — Tin plated copper alloys are quite common and can be sources of tin in scrap, although admiralty metal and naval brass (60% Cu, 0.75% Sn, bal. Zn) are more common contaminants. There are also large tonnages of phosphor bronze, containing up to 10% tin, which are commercially available also. The high price and scrap value of these alloys, however, sharply accent the need of scrap sorting. As an impurity, tin does not affect processing adversely, although it is claimed to induce fire cracking, especially with iron above normal limits. As little as 0.5%, however, commences to lower ductility and increase strength to a noticeable degree. Above about 4.0% hot working is not commercial. Cold working of tin-bearing brass is successful, but becomes more limited as tin increases because of the increasing work-hardening rate.

There are other minor impurities which can occasionally occur — among them are silicon from silicon bronzes such as Herculoy, Everdur or Olympic Bronze, and silver from silver-bearing copper. However, those elements best known and of most effect have been described. Further and more detailed information on the impurity situation can be found in the following:

D. R. Hull, H. F. Silliman and E. W. Palmer, "Effect of Antimony on Some Properties of 70-30 Brass", Am. Inst. Mining Met. Engrs. Tech. Pub. No. 1552, 1943.

W. B. Price and R. W. Bailey, "Bismuth — Its Effect on the Hot Working and Cold Working Properties of Alpha and Alpha-Beta Brasses", Trans. Am. Inst. Mining Met. Engrs., Inst. Metals Div., Vol. 147, 1942.

B. W. Gonser and C. M. Heath, "Effect of Chromium on the Grain Growth of Brass", Trans. Am. Inst. Mining Met. Engrs., Inst. Metals Div., Vol. 128, 1938.

M. Cook and H. J. Hiller, "Effect of Different Elements on Annealing and Grain Growth Characteristics of Alpha Brass", J. Inst. Metals, Vol. 49, 1932, p. 247.

J. Dudley Jevons, "Metallurgy of Deep Drawing and Pressing", John Wiley & Sons, Inc., 1942.

J. L. Gregg, "Arsenical and Argentiferous Copper", Chemical Catalog Co., 1934.

Metals Handbook, 1939 Edition.

The moral of the whole story is: "Segregate your scrap".

The author re-emphasizes some elementary facts concerning secondary radiation, often overlooked by X-ray operators, and indicates how some simple experiments with usual equipment will determine the best available combination for sharpening the recorded images

Improving X-Ray Radiographs

by Filtering Out Secondary Radiation

IT IS WELL KNOWN that radiation is divided by physicists into the following two classifications:

1. The focal or primary radiation which emanates from the target of the X-ray tube.

2. Secondary, or off-focus radiation which may be described as that radiation which emanates from sources other than the tube focal spot.

Secondary radiation is detrimental to radiographic quality, principally by impairing contrast in the film. There has been much attention given to the interesting fact that many materials, exposed to penetrating radiation, become themselves excited and throw off rays of various sorts. The secondary radiation excited in the metallic object being examined is a specific case. However, this present note concerns itself with another — and frequently more important — source of secondary radiation, namely those portions of the X-ray tube itself other than the "focal spot". We will endeavor to show how this can be appraised and prevented from reaching the film during normal exposure.

The most practical and yet simple method of studying secondary radiation from the X-ray tube is by exposing films through a small opening in a sheet of lead, the size of which should allow passage of the primary X-ray beam only. This "pin-hole camera" enables us to study off-focus radiation, whereafter steps to reduce its detrimental effects can be undertaken. By this method any radiation which projects an image on a film, other than the image of the tube target, is obviously secondary in nature, unnecessary in the formation of the image of the tube target and therefore detrimental in its effect of reducing film contrast and increasing density by its fog-like action.

X-ray inspection laboratories, as a rule, are equipped with various apparatus, accessory to the X-ray tube transformer and control, for establishing exact procedures for the detection of flaws in defective materials. This is the purpose of the inspection. In this sense it is advisable to utilize the various apparatus in trial exposures; they would be of little use if they were thrust into a corner and ignored, when actually they are designed for a specific purpose and might solve a serious problem.

For example, we set the X-ray tube with focal spot 20 in. above a lead covered table. Midway was placed a horizontal sheet of lead ⅛ in. thick, through which a hole 1.5 mm. (0.06 in.) was drilled. The film selected for the exposures was Eastman Kodak Type "A", because of its fine grain, high contrast value, especially adapted to radiography wherein good sensitivity is required.

By Robert Taylor
Consultant in Industrial Radiology
Spokane, Washington

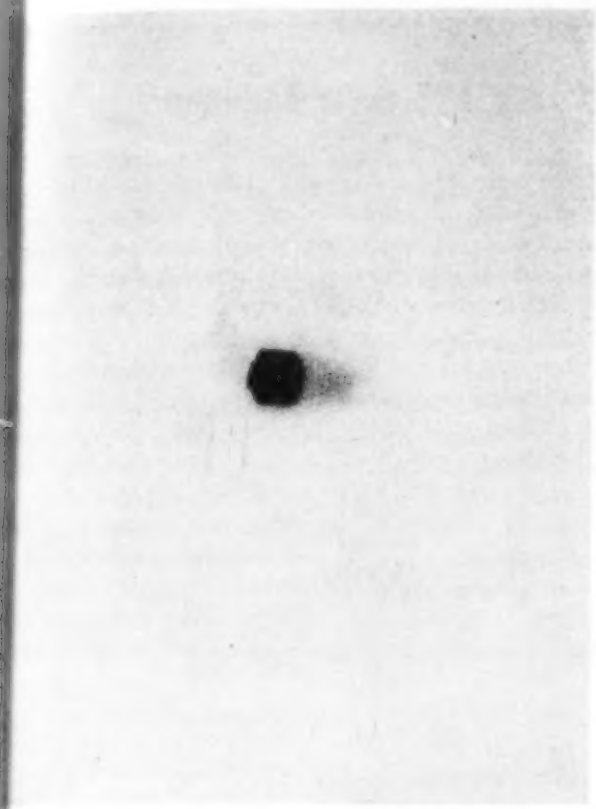

Fig. 1 — Direct Exposure Shows Not Only the Focal Spot but Image of Entire Electrode. Radiation From Window of Tube Envelope, as Well as Profuse General Secondary Radiation

The customary exposure holder with thin lead foil backing was used, the film being inserted within after the black protective paper was removed from each film. Voltage on the tube was maintained constant, and time varied — depending on the screens used — to maintain a constant film density of 1.5 as measured by a photometer.

The initial experiment (Fig. 1) was a direct exposure, that is nothing was used but the above mentioned arrangement of tube, pinhole, and sensitive film. If radiation came exclusively from the focal spot (about 0.20 in. diameter) the conditions are such that the film should show its image, fairly sharply defined (and about 0.30 in. diameter).

The film actually showed not only an image of the target, but also of the entire electrode face, indicating that this entire area was a source of X-radiation — an indication of poor electrode design. The increase in density surrounding the electrode image indicated that secondary radiation was also reaching the film from the window of the tube envelope. Finally the entire background showed profuse secondary radiation, indicating that the method of exposure was producing poor photographic results.

The second exposure was aligned in the same way as the first, except for the addition of a filter of copper sheet, 0.04 in. in thickness, placed close to the tube. Figure 2 is the radiograph made, which illustrates the following:

Image of the anode face and tube window is still prominent, indicating that the copper filter cannot cut off secondary radiation from this source except if of "prohibitive" thickness. About one-third of the secondary radiation visible against the film background was cleaned up.

A third exposure was made after removing the copper sheet but placing a Potter-Bucky grid immediately over the film holder. The exposure was intended to determine whether the grid would reduce secondary without a filter. Figure 3 illustrates the following:

Off-focus secondary radiation emanating from the face of the anode is still quite visible, indicating that the diaphragm did not absorb this radiation. This radiation evidently lined up with the grid in practically the same manner as did the radiation emanating from the tube target.

It was then decided to take a second exposure with the grid, interposing near the tube the same copper filter used for study No. 2, to determine whether additional secondary could be eliminated by using both filter and grid. Figure 4 shows the film obtained. Its quality was considerably improved, the only appreciable secondary radiation being that from the anode face. Both the filter and the grid failed to cut out this.

One additional study

Fig. 2 — Same as Fig. 1 Except for 0.04 In. Copper Near the X-Ray Tube. Principal effect is to reduce the profuse general secondary radiation

Fig. 3 (above) — Same as Fig. 1 Except for Potter-Bucky Grid Immediately Above Film. Principal effect is to cut off some radiation from the tube envelope

Fig. 4 (right) — Set-Up Using Both Copper Screen and Bucky Grid. Secondary radiation is cut out, except that from the electrode face

was decided upon, utilizing the copper filter at the tube and one lead foil screen, the latter replacing the grid, in contact with the film. Thickness of this front lead screen was 0.005 in. Figure 5, the resulting film, revealed these facts:*

1. No scatter was visible.
2. Secondary radiation emanating from the anterior portion of the anode electrode was absorbed by the lead foil.
3. A small area of increased density appeared slightly in front of the image of the target, found to be an artifact in the lead foil.

Conclusions

The studies herein illustrated apply only to one X-ray tube and one machine; however, the method is applicable to any tube or machine. It offers the most practical means of determining sources of secondary radiation and a manner of minimizing its detrimental effects. Clarity and contrast of films are thereby achieved.

X-ray inspection laboratories starting operation or those in operation which have not carried out similar studies may, by doing so, disclose many interesting facts.

*Editor's Note: The characteristics of the films were plain even on photographic prints, but unfortunately cannot be reproduced in an engraving.

Fixing Phase Boundaries

It was the consensus that X-ray diffracti patterns were a useful adjunct to the more co ventional tools of metallographic analysis (cooli curve, dilatometer, microscope, magnetometer). Mi Gayler cited several useful examples of X-ray wo other than the determination of the atomic archite ture of metallic phases: The high temperature X-r camera determined whether phases were retained quenching; they disco ered super-lattices; we able to discover co working effects, and t first signs of precipitati and recrystallizatio They were especially va uable in finding ternar

*Notes on a round tab discussion "The Determin tion of Equilibrium Di grams by X-Ray Methods" *Journal*, Institute of Meta (London), 1943, Vol. 6 Publication 931.

Fig. 5 (below) — Copper Screen Near Tube and 0.005-In. Lead Foil Next to Film Cuts Out All Noticeable Secondary Radiation During a Direct Exposure

phases in preliminary studies of ternary diagrams, when the three binary diagrams were known. On the other hand X-rays had yet to become useful for studies above the solidus, for interpreting twinning phenomena, and for detecting earliest appearance of extra phases. W. Hume-Rothery called attention to the fallacy of assuming that powders or filings (preferred by roentgenologists for diffraction studies, rather than using the less accurate back reflection camera) had the same structure as the solid piece from which they were derived. Suppose the original ingot had a coarse grained, two phase structure. Fine filings made from this might either be *(a)* a particle of Phase I, *(b)* a particle of Phase II, or *(c)* duplex. If now this powder were heat treated in a way supposed to cause reaction between Phases I and II, only particles *(c)* would respond, and the reactions would be much slower in the powder than in the lump. This objection does not apply when precipitation phenomena are being studied in a material originally of a single phase. However there is danger of contamination by surface films or adsorbed layers on the particles; but this could generally be avoided by proper precautions. Some alloys are so sensitive to transformation by cold work that obviously powders do not represent the solid metal.....As to accuracy, Professor Owen (by comparing the results of various types of researches) believed that X-ray examination of quenched specimens would determine phase boundaries to an accuracy of 0.1 to 0.3 atomic per cent. While this is none too close for the scientific researcher, it is usually more than ample for industrial problems, as commercial alloys are frequently not in the state of equilibrium.

Critical Points

By the Editor

I Helped celebrate the 25th anniversary of Army Ordnance Association in New York City, where the show was stolen by two Guadalcanal veterans, puckish Col. Krulak of the Marines and convalescent Gen. Waldron, Army artillerist. Both brought good news to all Americans, but especially to parents whose sons are fighting there, stated convincingly and without reservation, that our standard weapons are far better than our enemy's, even though the latter were developed especially for jungle fighting.

Peace is our prize

Garand rifles came in for special praise, thus confuting early critics; M-19 light machine guns never jamb from overheat; antitank grenades and bazookas are equally effective against other hard obstacles and even Jap infantrymen. Special tropical equipment recently getting into action is even better — a point obvious to the most casual observer of the captured antitank and anti-aircraft guns (both Jap and Nazi) exhibited alongside American counterparts. Over and over, speakers emphasized that much of this superiority has been built into our equipment since hostilities commenced, thus emphasizing the successful cooperation between Army ordnance and American science and industry. Science, engineering and research have taken their entire mode of thinking away from peace and quiet to the problems of noisy war — a fact not nearly as widely known as the conversion of industry, large and small, which has produced quantities beyond comprehension. Over and over, it was stated that these improvements were achieved by free men, and progress could have been smothered at any time by a politico-bureaucratic blanket intended to "coordinate and direct" the work. The oft-used phrase "ordnance-industry team" really includes this research and development function; in fact, the achievements of research were keynoted at the meeting rather than the adaptability and productivity of industry. Hence it was logical that Charles E. Wilson, WPB's vice-chairman, should come out strongly for a continuance of this ordnance-industry-research program, so that our fighting men's

equipment, either on land or ocean, in the air or undersea, be constantly modernized — constantly ready in sufficient volume, so good, so superior to that of any attacker that a second Pearl Harbor would, if contemplated, be dismissed as suicidal. Peace cannot be insured merely by pacific intentions, as 50 years of American history proves. Pacific intentions, *plus* the ability to punish attackers instantly, devastatingly and overwhelmingly, may bring peace as our prize.

FROM MY ORDNANCE NOTEBOOK:

Maj. Gen. THOMAS J. HAYES of Ordnance's Industrial Division — Over-all ordnance production (dollar value) leveled off during 1943 and will remain about stationary in 1944. Unit costs have been cut about 82% in two years....The A.E.F. had to use European arms in World War I; this war is being fought on all fronts largely with material designed and manufactured in the United States.

E. B. YANCEY of du Pont — Six years of research were required to improve smokeless powder so as to be less hygroscopic and produce less muzzle flash....Improvements in old powder plants, short-cuts in old processes, and new powder making processes have, in three years, rendered unnecessary the construction of one-third the anticipated number of "lines" and saved several hundred million dollars on plant alone.

Maj. Gen. GLADEON M. BARNES of Ordnance's Technical Division — We have dozens of new, unpublicized weapons now on the battlefields; even so, the greatest activity in ordnance engineering today is on several hundred special weapons for specific theaters.

Capt. W. M. MOSES, U. S. Navy — A radically new weapon ordinarily will require 12 to 18 months to design, build, test, get into production and deliver to the front. (NOTE: The 75-mm. aircraft cannon required four years.)

Victories by researchers & technologists

W. J. MEINEL of Heintz Mfg. Co. — New ideas can be introduced into old devices with surprising speed; an improved and enlarged gun mount was completely engineered, detailed drawings made, and production of parts started in three days.

FRANK B. JEWETT of Bell Telephone Laboratories — More than 20,000 scientists and technologists scattered throughout American laboratories are working on war projects supervised by the National Defense Research Committee, developing new tools and scientific principles to a place where the military men can appraise their value.

CLIFFORD ROBERTS of United Shoe Machinery Corp. — Research *can* be hurried in an emergency....The Army's technologists are *good*, as good as any similar group in industry....Competent technical and scientific personnel are as scarce as Jap prisoners.

THRILLED by sitting in the engineer's seat in a diesel freight engine (or rather four coupled engines and motor-generator drives, each in its own car) and imagining myself at the throttle of a trans-continental run, eating track at 70 miles an hour, and so, perhaps, experienced in aging pulses that same throb that sends boys today into the Air Forces! These huge prime movers, made by Electro-Motive Division of General Motors Corp. at LaGrange, Ill., have set really amazing performance records. Diesel electric passenger locomotives are expected to run 1000 miles a day *every day*. A notable performance among many are the Burlington Denver "Zephyr" with 2,270,000 miles in seven years. So was doubly interested in the intricate weldments forming the engine crankcase. The standard G.M. railroad engine is a V-type, 2-cycle diesel made either as an 8, 12 or 16-cylinder combination; the case is really the main frame containing cylinders, water jackets, and bearing supports — in fact, all stationary parts from cylinder head to oil pan. The 16-cylinder crankcases (for a typical freight engine unit) are 15 ft. in. long, yet accurate enough after welding and stress relief for only $\frac{1}{16}$ in. machining allowance. Especially interested in the long line of welding positioners, each one massive and tall enough to juggle a 15-ton assemblage; also in the extensive use of Unionmelt for Tee joints.....JOHN HRUSKA, director of test and inspection, said that manganese-molybdenum, high yield steel plate had been used in the engine case for about seven years. It analyzes 0.90 to 1.10% manganese, 0.40 to 0.60% molybdenum, and 0.18 max. carbon. Other than on the carbon limitation, the most insistence is placed on properties: 72,000 psi. min. ultimate, 43,500 min. yield, and 22% min. elongation in 8 in. (the latter not so easy to meet in as-rolled plate less than 1 in. thick). In this steel carbon is held low for weldability, manganese is up for strength, molybdenum is added to correct temper brittleness and produce tough steel at low temperatures. This and all other metals considered for locomotive construction are tested in impact at 25° intervals from +75 to −100° F., and the change from notch-tough to notch-brittle (which occurs above zero in firebox steel) must be below

Weldments and metals for diesel locomotives

—50 F.....Another item of sound modern metallurgical practice is found in the axles—obviously of most importance for safe railroading. These are normalized and drawn forgings of 1050 steel, machined and ground all over, then magnafluxed. If there is the slightest surface discontinuity the axle is scrapped—harsh treatment it would seem sometimes, but nevertheless good insurance against fatigue failures..... Main gears pressed on these axles are cut from a forged, normalized and drawn ring of 6145 steel. The gear is then hardened and drawn to Brinell 400 to 450, and the 5-in. wide teeth are shot blasted to put the surface into compression and so increase their endurance. The rim is shrunk at 600° F. on a mild steel center and the combination pressed onto the axle. Both pinion and gear are rough to the touch after shot blasting, but HRUSKA says the pock marks smooth out quickly along the contacting elements in early operation, and the gear runs quietly and efficiently.

DATED my own acquaintance with aluminum research by attending a recent meeting at Alcoa's central laboratories and hearing FRANCIS FRARY, director, tell of his first visit to New Kensington. It couldn't have been much earlier than mine, for we both recall the meager facilities used by a half-dozen men, upstairs in the cooking utensil plant—described by EARL BLOUGH, then chief chemist, as "The Home of Poor Research". Great indeed has been the expansion into the present palatial quarters on the hill, plus the extensive research laboratories in Cleveland and East St. Louis. Great indeed have been the achievements of the ever-increasing company of investigators directed by FRARY, BAKKEN, EDWARDS, TEMPLIN and DIX. Appraisal of progress is difficult. Perhaps it would be well to rely on some exhibits adorning the laboratory halls, suggested by the staff as representing the outstanding successes of a quarter-century. Among them are the perfection of Alclad, of 24S alloy for aircraft, and the new "super strength" X76S (an entirely new family of alloys whose composition and heat treatments are still censored). Also: Free-cutting aluminum, improved casting alloys, and precise studies of forging alloys and forging methods which have produced so amazing an article as a finned cylinder head for aircraft engines. Alzac (high reflectivity surface) and alumilite (oxidized weather resisting surfaces) were mentioned, as well as the long-time corrosion studies and their interpretation by statistical methods—greatly helped by the recently perfected tests for solution potential. Standardized mechanical test methods, searches for fatigue or endurance limit (familiarly referred to as "the little man who isn't there"), and tests on life-sized parts for perfecting design methods—all have given the engineering user a great volume of necessary data. Standardization of chemical analysis and the development of spectrographic methods (some six million determinations were made in Alcoa control laboratories in 1943) have saved uncounted hours of analysts' time. Numerous projects concerning the refining of bauxite into alumina led up to the successful lime-sintering process for low grade ore and red mud, but also guided various Governmental agencies in appraising the many schemes submitted for getting wartime aluminum from clay. Last I might mention the publications as a prime achievement; in fact, the beautiful brochure on the laboratories recently published devotes half its space to listing nearly 500 notable contributions by the staff to various phases of metals technology.

Fruits of 25 years' study of aluminum

ONCE UPON A TIME asked myself the question "How much has technology and organized business meant to the steel worker—and to the rest of us—in terms of labor saving?" and found my answer in ENDERS VOORHEES' recent testimony before the Senate Finance Committee. He compared 1902 (a year of full production in the steel industry) with 1942. Type of product has remained about the same—the Steel Corp. always has specialized in tonnage items. Change, if any, has been toward product requiring more time and attention.....In 1902 the Corporation had 168,000 workers; in 1942 just double that number, but total number of hours worked was up only 13%. In 1902 the steel worker (on the average) put in 3570 hr., or 12 hr. per day for 300 days; in 1942 he worked 2020 hr., or 6.7 hr. per day. In other words, technology and organized business had cut the work day, or work week, or work month (however you want to figure it) *almost in half!* But that's not the whole story. In each hour of the work that was done the 1902 worker made 30 lb. of steel; in 1942 he made 60 lb.; thus, he now makes 13% more steel in a short day than he did in a long one....."But what has organized business and technology to do with this?" you ask. Compare the record of these costs with that of the house you live in. Bricks are still laid the same as they were in Pharaoh's time—only much more slowly.

Half the labor saved

Parts for small, high duty condensers and liquid coolers, and for machinery covers to resist corrosive spray, are made of cupro-nickel sheet, welded to steel plate in hydrogen brazing furnace, using thin copper film for joining material

Steel Plate Clad With Cupro-Nickel Sheet

DURING THE PAST two years an immense number of schemes were used to save critical metals, and many of them will doubtless survive the need of conservation. I refer to those projects that result in a better and more adaptable machine part, or a cheaper one good enough for the service requirements. It may be interesting to record the experiments leading up to the production — in a radiator manufacturer's plant — of an interesting and economical substitute for solid cupro-nickel (70-30) in thicknesses from $\frac{1}{16}$ to 1 in., used on equipment subject to salt water spray and corrosive engine exhausts. Condensers, oil and water coolers, air cooled motors and generators, are some of the products that use such non-corrosive metal. It appeared quite logical to substitute mild steel, thinly clad with cupro-nickel. Steel clad with stainless, nickel, copper or lead has been an article of commerce, and we set about finding simple means of readily producing the cupro-nickel-steel combination which we called "super clad".

In the particular application first discussed, the inner surface of air-cooled generator units was exposed to corrosion and electrolytic action of salt water, while the outer surface was exposed only to the air, and sometimes oil splatter. Figure 1 shows such a section, made from solid cupro-nickel; under the new method of super clad it has only 0.032 in. cupro-nickel on the inner surface. Where all surfaces are attacked by corrosion, another application would be necessary in order to maintain these resistant qualities. In this particular instance, the original weight of solid cupro-nickel section averaged 22 lb., as shown in Fig. 1, while in the super clad application the amount of cupro-nickel used is about 12 oz. with the balance of mild steel stock. The combined section was approximately 2 lb. lighter in weight, thus making the complete unit of six sections 13 lb. lighter than the original. As to the conservation of the vital materials, nickel and copper, it is estimated that 82 to 90% saving was established by this new product. In the single model under discussion, it resulted in a saving of about 12,500 lb. of nickel and 32,000 lb. of copper. (This was only one model.) As to the cost: Super clad reduces the original cost per unit by $50 to $60. The section illustrated in Fig. 1 in its original form cost approximately $1[illegible] for material, while super-clad with one clad surface costs approximately $2 which includes material and actual labor for facing off four sides.

Experiments were started with three methods of approach: *(a)* Joining or laminating of steel and cupro-nickel by either plug or slot welding, or by complete electric welding of transverse and longitudinal seams. *(b)* Resistance welding by spot and seam methods. *(c)* Use of a hydrogen brazing furnace. Working with three methods, advantages and disadvantages were

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established for each, but the last procedure proved most successful. Although the first and second methods were not adaptable to our problem, they will be briefly explained since the ideas might prove useful in other applications.

Plug and Spot Welding

Plug welds, 1 in. diameter, were staggered 1 in., center to center. A $\frac{3}{32}$-in. cupro-nickel coated electrode was used. This operation warped the thin sheet overlay of cupro-nickel and also developed many irregularities in its surface, caused by the heat from the arc. Later it was found that the thicker the cupro-nickel, the less irregularities and warping occurred.

The same characteristics were found in slot welding, even though handling during the operation was simplified. Less slag was trapped in the fusion area.

A seal-tight surface between the cupro-nickel and the steel was finally accomplished by arc welding with a coated cupro-nickel electrode. Cupro-nickel plates were clamped to the steel backing and tack welded along transverse and longitudinal seams. Then, by staggering the welding, all seams were completely welded. All joints were sealed, but some of the overlays warped and formed slight air pockets between the cupro-nickel and steel. Then we thought of combining this plan with slot welding, and it proved to give a satisfactory piece of material, but since all surfaces had to have machined finishes, the cost was too high, especially on $\frac{1}{8}$ to $\frac{5}{16}$-in. clad thickness.

The samples of spot welded overlays in the second group gave a few good specimens, but again were warped and occasionally burned at the cupro-nickel surfaces. This method had a limited application to light gage materials only. Seam welding (overlapping spots) gave good results on $\frac{1}{16}$ to $\frac{1}{8}$-in. laminated material, but again the cupro-nickel burned when going to heavier stock and thus developed noticeable hot shortness. In all our experiments the materials were cleaned thoroughly before using. Points such as type and size of electrode, heat control and heat consumed, and method used for handling are not discussed at this time.

Automatic Brazing

The third and final method was the lamination of cupro-nickel and steel by hydrogen brazing. This proved to be the most successful.

Samples were started with 0.020-in. cupro-nickel sheet to $\frac{1}{16}$-in. mild steel plate, interleaved with 0.006 in. of electrolytic copper, and a special flux. Pilot runs revealed that the copper thickness should vary according to the thickness of steel and cupro-nickel. On many samples "copper spots" developed after going through the brazing furnace, although bonding was excellent and warpage very small. If only one side of the steel was covered with cupro-nickel, most of the samples distorted along the outer edges, thus developing a concave or "belly" material. This predominated on materials $\frac{3}{16}$ in. or less in wall thickness, and was probably due to the different coefficients of thermal expansion of the two components. However warped plates could easily be straightened out without affecting the bond.

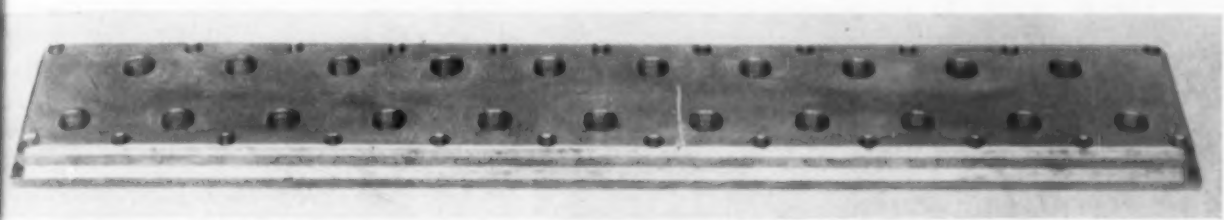

Fig. 1—Cupro-Nickel Header for Air Cooled Motor and Generator; Weight 22 Lb., Material Cost $10

After much testing on experimental pieces for the control of bonding, gas pockets, blistering, warpage and other items, a process specification was written to cover each application in the plant. Details of the following discussion will refer to the model illustrated in Fig. 1.

In the production of this material, parts must be carefully prepared in order to get a secure bond. The parent metal may be S.A.E. 1010 or 1020 steel, and must be cleaned and pickled free of scale, corrosion products, or grease of any nature. If production is high, electrolytic pickling should be used to save time; in the still method plates would require from 20 to 30 min. in the sulphuric acid pickle, while in the electrolytic tank the time could be reduced to 3 to 5 min. The cupro-nickel overlay and the bonding sheet of copper should also be thoroughly cleaned by washing and degreasing, then thoroughly dried to prevent re-oxidation. After being cleaned this

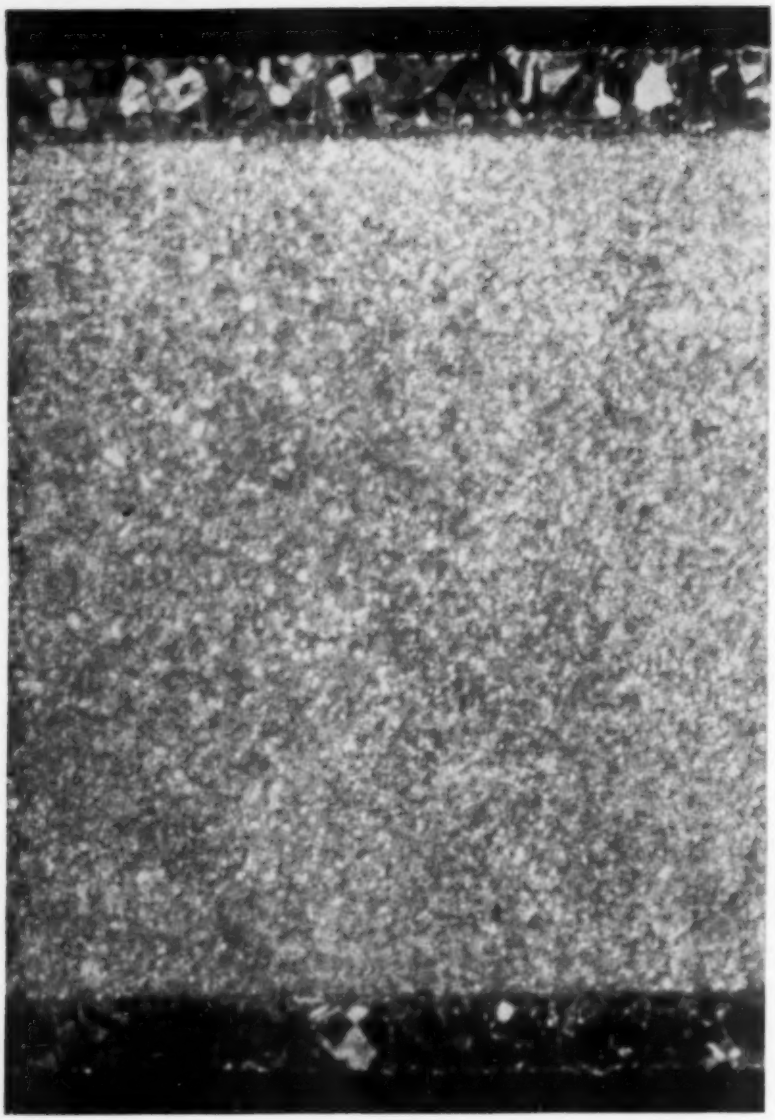

Fig. 2 — Cross Section of ¼-In. Super Clad Plate at 20 Diameters, Showing Zones Where Copper Brazing Material Has Diffused Into Both Cupro-Nickel Overlay and Steel Center

material should be used within the next 24 hr.

The binder consists of a copper sheet (deoxidized or electrolytic) varying in thickness according to the area and size of material to be produced. In addition, a flux was especially prepared to aid the bond. Care has to be taken with regard to the amount of flux used between these surfaces; too much would favor the retention of gases and the development of pinholes in the cupro-nickel surface, through which the bonding metal, copper, would be visible. If a proper and minimum amount was used there was a pronounced tendency for it to flow toward the outer edges as it melted. All plates — steel, cupro-nickel and copper — were made ½ in. longer and ½ in. wider than the desired dimensions, to trap the impurities, and the excess was later trimmed off, leaving a perfectly bonded area.

The parts, being thoroughly clean, are now ready for assembly, as follows: One side of the steel plate and the faying surface of the cupro-nickel sheet are painted uniformly with the flux, applied thinly over the entire area. The copper sheet is then placed upon this fluxed surface of the steel, and the cupro-nickel plate inverted with the flux side bearing on the top of the copper leaf. Particular care should be taken to line all three plates uniformly. This is essential and should be watched while placing the materials on the furnace conveyor. Both copper and cupro-nickel plates have a slight waviness in the thinner gages, therefore all three plates are weighted to bring the pile into close contact. In applying these weights a protective piece of carbon strip, the same length and width as the cupro-nickel plate, should be placed under the weights; this prevents any tendency for these weights to bond with the top surface of the finished material. The amount of weights will vary according to the job, but in our work steel cubes were uniformly distributed over the carbon strip, totaling 10 to 20 lb. depending on the area to be bonded.

Passing through on the belt conveyor of a hydrogen brazing furnace, the temperature was brought to 2050 ± 25° F. The rate of travel will vary with the thickness of stock. In our work we used 2½ to 3 hr. for going through the furnace. In the cooling chamber the plates moved slowly until they reached temperatures of between 200 and 300° F., and then were moved from the conveyor to a skid. Plates sometimes warped a little after brazing, but little or no warping was found when *both* surfaces of the steel plate were clad with cupro-nickel. When cladding only one surface of the steel, warping was worse on thinner plates, but this was corrected in part by adjusting the speed of the conveyor belt in the furnace. Blistering on the outer surface occurred only when too many impurities existed between the plates, too much copper was used as a binder, or too much flux was applied — all matters which can readily be taken care of.

The correct amount of copper was also found by trial and error. First, the thickness will vary accordingly to the thickness of steel and cupro-nickel; the diffusion of copper into the steel plate is faster than into the cupro-nickel plate. On the other hand if the copper is too thick, then it will work through the cupro-nickel and be visible on the outer surface. After many samples were made, the following table was established:

Thickness of Mild Steel Plate	Thickness of Cupro-Nickel	Thickness of Copper
1/16 in.	0.020 in.	0.0015 to 0.002 in.
1/8	0.020 to 0.025	0.002 to 0.003
1/4	0.025 to 0.032	0.003 to 0.0048
1/2	0.032 to 0.047	0.003 to 0.0048
3/4	0.032 to 0.062	0.003 to 0.006

Sizes were quite various, some 40 different items being produced, ranging from 15 by 36 in. to 6 by 54 in. The latter formed a blank for three pieces about 6 by 18 in. in area.

On thin gage material (both steel and cupro-nickel) the thickness of copper should be kept to a minimum. Original pilot runs were with 0.006 in. copper on light gage material, but looking at the above table it will be noticed that this was far too much, the copper thickness being eventually reduced to 0.0015 to 0.002 in.

Figures 2 and 3 show the grain structure and bonding of these metals as viewed under the low power microscope. Work at higher power indicated that the copper sheet under the top cladding diffused deeper into the steel plate than it did on the lower side. This also showed up in the hardness readings. In manufacturing one unit, hardness records were kept from start to end of run. The range of hardness of the mild steel section was Rockwell B-59 to 62 before brazing, while the cupro-nickel plates ranged from B-42 to 46. After brazing, the steel plate was harder near the bonding zone, developing B-62 to 66 on both edges. An increase in hardness was observed in thick steel plate as far as 1/4 in. from the bonding zone. In comparing the readings from both edges of single sheets it was noticed that the top section, that is, the plate of cupro-nickel that was on top side as it was going through the brazing furnace, had lower hardness readings than on the lower side. The penetration of copper into the top cupro-nickel sheet was about the same as into the bottom one.

In straightening these plates a set of power rolls or a hydraulic arbor press was employed, depending upon the thickness and the amount of warping existing. After straightening, the plates were sheared to required size. In all operations where rough burrs develop, they should be on the steel side. It was found that production was increased when cupro-nickel was kept at a minimum thickness while the steel was at the maximum, thus increasing feeds and speeds during machining. Machining should progress from the cupro-nickel side to the steel plate, rather than from the steel plate to the cupro-nickel, thus giving better production and preventing any fracture of the bond. Machining, especially drilling, also revealed that the bonding of these materials was very good.

Although this material is limited in its applications, it will be of great advantage, not only in conserving expensive nickel and copper, but also in saving weight. Where high corrosion and electrolytic resistance is required, this product has many possibilities of value for industry in the future.

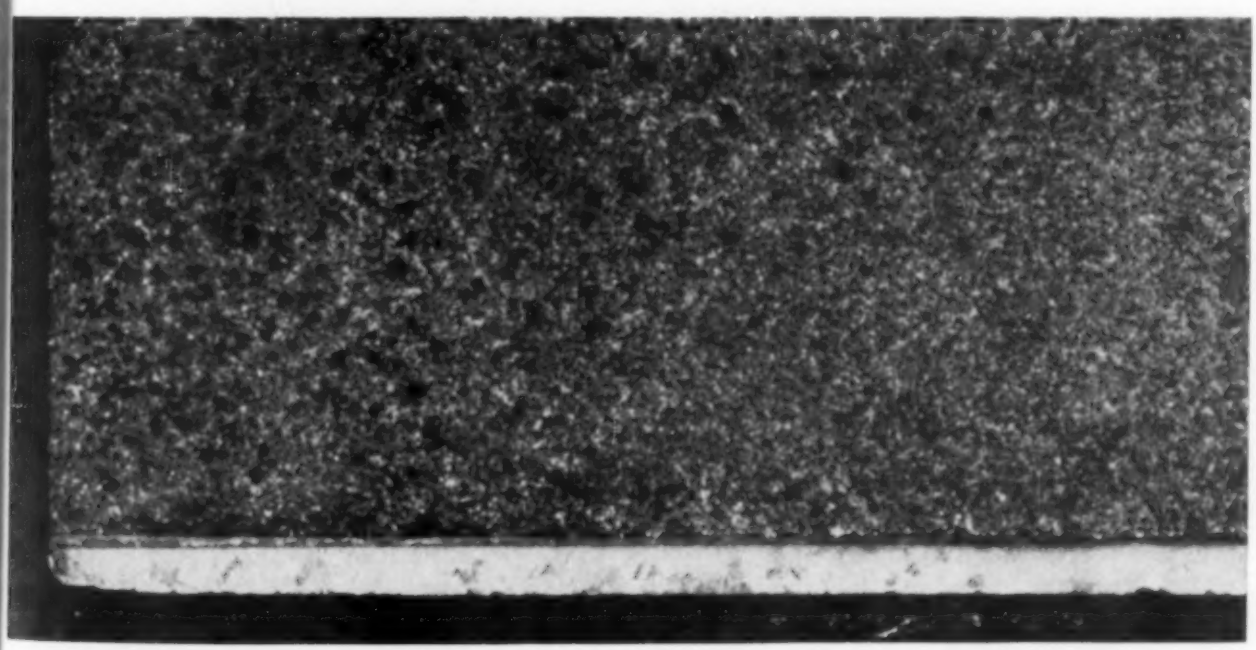

Fig. 3—Corner of Header Plate Shown in Fig. 1, Indicating the Flow of Copper Bonding Material to Fill Slight Irregularities Between Cladding and Steel. Magnified 20 Diameters

1942 Recipient, A.S.M. Medal for the Advancement of Research

Roy Arthur Hunt

President, Aluminum Co. of America

THE FORWARD LOOKING ATTITUDE of Aluminum Co. of America toward research, which has been one of the outstanding achievements of the company, comes about naturally. Its president, ROY ARTHUR HUNT, got his start as a young man when the metal was in the purely experimental stage and during his life has grown in executive experience as the commercial uses of aluminum have expanded.

He was born in 1881 in Nashua, N. H., and was less than a year old when his family moved to Pittsburgh, where his father, Capt. Alfred E. Hunt, a pioneer metallurgist, was instrumental in organizing the Pittsburgh Reduction Co. for the purpose of reducing aluminum by the electrolytic process, discovered two years previously by Charles Martin Hall. He received his elementary education in the Pittsburgh Public Schools. His preparatory years were spent at Shady Side Academy in the same city. He graduated from Yale in 1903.

Long before he left college Roy Hunt decided on his future career and during summer vacations he prepared himself for it by working as a machinist's helper in the New Kensington plant of the Pittsburgh Reduction Co., later to become Aluminum Co. of America. After his graduation he became a mill clerk at New Kensington, and two years later was transferred to the cost department. After a year of this kind of work he was promoted to the position of assistant superintendent of the New Kensington plant.

In 1907 the corporate title of the Pittsburgh Reduction Co. was changed to its present name, Aluminum Co. of America. The following year Mr. Hunt was made superintendent of the New Kensington works, a position which he held for six years. In 1914 he was named general superintendent of all the company's fabricating plants, with headquarters in Pittsburgh; five years later he was appointed vice-president in charge of both fabricating and reduction plants. On June 4, 1928, he was named president of Aluminum Co. of America, succeeding ARTHUR VINING DAVIS, who became chairman of the board of directors.

Under the guidance of Mr. Hunt the Aluminum Co. has been the leader in the research and technical development of a metal which has had its entire industrial growth in the past 55 years. The matter is adequately, if briefly, described in the citation conferring the A.S.M. Medal for the Advancement of Research:

"Growing into a position of executive responsibility in the Aluminum Co. of America about 25 years ago, ROY ARTHUR HUNT found that notable predecessors in the persons of Hall, the inventor, and Hoopes, the engineer, had developed the processes for the production of pure aluminum to such a position that ample and increasing quantities were being put to man's use. Despite this apparently satisfying situation, Roy Hunt and his associates felt that if this relatively soft metal could be appreciably strengthened its use could be expanded and diversified. Many attempts to produce strong alloys in the plants had brought nothing but failure; the problem required extensive research directed toward practical ends, and this was initiated forthwith by the establishment of Aluminum Research Laboratories.

"Roy Hunt's support, through prosperous and adverse years alike, of these laboratories has been constant and unfailing. A large number of strong alloys, heat treatments, and processes, have been developed, resulting in many combinations of useful engineering properties. The vision of a greatly expanded strong aluminum alloy industry was realized in time to provide the main structural elements for the present enormous aircraft production program. A large group of technical experts had been assembled and were available to aid in the necessary expansion of aluminum reduction and fabrication capacity to meet the needs of the present emergency. Likewise the fundamental principles evolved during the research on aluminum have contributed to the solution of metallurgical problems in other fields. Finally, the entire metal industry has gained inspiration from this courage and faith in research."

In 1938, with war clouds gathering over Europe, the company began a study of its ability to meet any demand for aluminum which might come from England or France. Disregarding the large stock of aluminum then on hand and the apparent small requirements of the armed forces of the United States, the company began an expansion program which, with additions since America got into the war, has called for a capital expenditure of more than $250,000,000 of the company's own money and credit.

Today, Aluminum Co. of America is playing a vital part in the war effort. In addition to the increase in its own ingot capacity, Alcoa's fabricating facilities for various commodities have been increased from seven to 45 times. The company has given freely of its experience and know-how in building for the government, without profit, a large number of aluminum and alumina plants owned by the Defense Plant Corp. but built and operated by Alcoa.

Consumer Control of Quality by Inspection

THE SERIES of short talks printed below was given by six experts at a group meeting on the general subject of "Quality Control" held at the national convention of the American Society for Metals in Chicago last October. The subject was considered under three general heads.

A—Considerations Having Most to Do With the Inspector

Separating Important From Unimportant Inspection Operations

By Arthur W. F. Green
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THE APPROACH to the subject assigned me is to evaluate inspection. I make bold such an evaluation: Inspection separates the important from the unimportant when the conception differs — between *(a)* just plain checking up on the other fellow, or *(b)* controlling the quality for use of the product being manufactured. For some years I have worked in an industry wherein the latter conception has been a guiding star.

It must not be forgotten that our first artisans working as individuals created and produced things as a whole. For example, the old gun-smith was his own procurement officer, his own machinist, his own inspector, his own assembly man and finally, his own salesman.

Mass production has integrated manufacturing procedures in almost direct proportion to product applications. The basis for my thoughts about inspection is that, properly controlled, it provides for saving materials and manpower and insures quality in the finished product. It is also viewed from the standpoint of the aircraft engine manufacturers who make rigidly inspected products.

One of the aircraft engines now in military use, and garnering high praise for its performance in combat, was not offered to the military agencies until it had undergone approximately 100,000 hr. of engineering design, testing, refinement and establishment of dependability. Once a design has been proven by such testing, and the bill of materials established, the specified materials, the production and operation procedures, and the quality standards are practically "frozen". The quality engineer, materials engineer, materials production engineer, the chief metallurgist, and the chief inspector, with their forces, have their blueprint established and their course of procedure detailed. In these years of testing and development, the important has been separated from the unim-

portant: the former emphasized and the latter minimized.

There are few manufactured articles that require so much attention from an inspection standpoint as does the aircraft engine and its sundry component parts. Few man-made articles carry into their field of application and use so great a provision for producer responsibility. Few power producing units, whether for production of electrical energy, transportation, or other requirements, can equal the horsepower-to-weight ratios of the aircraft engine, which is approximately 1 hp. per lb. of engine weight.

Aircraft engine manufacturers, recognizing the meaning of producer responsibility, have built up a control of production, not only of the engine as a whole, but for the many individual parts, by installing well-rounded and controlled inspection procedures and inspection departments. The ratio of inspector to worker manpower in these plants varies from 1 to 4 to 1 to 7, averaging 1 to 6 — that is, one inspector for each six workers. Such a numerous personnel warrants the preparation of minutely detailed instruction sheets — nay, requires it — else there will be hopeless variation in viewpoint, man to man, or plant to plant.

Material controls for wood, plastics, rubber, paint, enamel, varnish, ferrous and non-ferrous metals, cloth, paper, lubricants, and all other materials, are exercised through the use of specifications either as developed by the individual engine manufacturers, or by governmental agencies or specification writing bodies, such as the American Society for Testing Materials, Society of Automotive Engineers, National Petroleum Institute and American Iron and Steel Institute.

Exercise of control is through the materials laboratory, where chemical, physical, X-ray, spectrographic and photographic procedures are used. Plant inspection control includes visual, magnetic, magnaflux, gaging and measuring devices. There are few items used on an aircraft engine which do not require a number of such control procedures and devices. The aircraft engine is truly a dynamic thing.

Every engine manufacturer lists some parts for engine use which do not require the same detailed inspection as do many other parts. Such separation of the very important from the less important has been the result of experience with engines on the test block and in service. For example the amount of inspection required for a cylinder hold-down stud in a radial type engine is obviously much more detailed than for a screw used for attaching a magneto cover.

The growth of the aircraft engine manufacturing industry through the medium of licensees both at home and abroad, and the necessity for expanding the production of so-called purchased parts from outside vendors, has been attended with a mutual exchange of engineering and manufacturing ideas and details. This has constituted one of the major contributions of a precision manufacturing industry to the war effort of the United Nations, and a vital factor in the war's trend in our favor.

Unfortunately, and particularly insofar as purchased parts manufacturers may be concerned, there have been a number of instances where new vendors contracted to make engine and accessory parts without giving complete study to the use requirements of the parts they make. There have been many cases where issue has been taken concerning both engineering and inspection requirements for parts to be made, because the manufacturer has viewed the particular part he was to make as an entity unto itself, rather than a significant part of a precision assembly.

Unfortunately, there has been and there continues to be a marked tendency, particularly among the newer producers of raw materials which go into aircraft engine manufacture, to ask for deviations and substitutions against specified materials and changes in the inspection requirements against such materials. The aircraft engine manufacturers are not unappreciative of the demands their rapidly expanded requirements have made on the steel, aluminum, magnesium, plastics, rubber and other raw material producers. Rather, there is a feeling that we may have failed to educate our newer friends along the line of our producer responsibility. We may have failed to show them the fundamental reasons for our so-often called "crazy" specifications and quality requirements.

The facts are that we are an industry based primarily on engineering design and procedure. Our inspection departments are not set up to alter or change materials or procedures so as to benefit production and sacrifice any one point of *producer responsibility* for the engines. Our specifications for material and quality control are based on engineering testing and approval.

If this deviation from my assigned subject is disappointing to most of you, accept my apologies. The separation of important from unimportant inspection operations — my specific assignment for discussion — is with us a definite procedure. But, when an aircraft engine fails in service, there is only one way for a plane to go, and that is down. There are no turnouts, no by-ways, no repair shops on the air lanes!

The Personal Equation in Inspection*

By John W. W. Sullivan
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THESE REMARKS directly concern the inspection supervisors who apply statistics to consumer acceptance control. Their main theme is also pertinent to other inspection supervisors, because successful management recognizes that the supervisor, as a human being, is a more important variable than any variable in the particular inspection system employed, the material being inspected or its method of manufacture.

The personal equation in inspection has not been reduced to a quantitative expression, because the human personality has not yet been expressed reliably by a number or a formula. Experience indicates that when a gage block is carefully placed in a cabinet at the end of the day's work, it is highly probable that the block will have the same dimensions and other characteristics on the following morning, making due allowance for any temperature change. When a supervisor in a happy mood goes home, the degree of assurance that he will be in the same mood the following morning is unknown. His "dimensions and other characteristics" at 8:00 a.m. may resemble only faintly those at the preceding 5:00 p.m.!

However, there is a well known and successful sales formula which, if properly used, can yield excellent results with inspection supervisors. It is as follows:

Attention + Interest + Desire = Favorable Action

If an inspection supervisor is not using a sound application of statistics to his inspection, very likely he will have to be "sold" on the idea of changing to such an application. The personal equation in inspection can therefore be expressed, in all probability, as a sales problem.

The average inspection supervisor must be shown that this application of statistics to acceptance inspection is not a dry collection of charts and calculations. Rather it is a very handy tool which has vitally important advantages to assist the supervisor in organizing and directing his work. These advantages are:

1. Inspection time usually can be reduced.
2. Material usually can be conserved by reducing the amount of destructive testing.
3. The use of testing equipment can be reduced.
4. Carefully analyzed inspection data usually can be made to yield constructive information, revealing specific causes of defects which must be removed to improve quality.
5. Production of defective material can be appreciably reduced.

The inspection supervisor must be shown, after the production process is in control, that additional advantages result, such as:

A. The reduced volume of inspection decreases inspection time during which finished products cannot be shipped.

B. Storage space for housing finished products awaiting shipment can be reduced.

C. The actual inventory of finished products can be reduced.

Especially, he must be sold on the following advantages of a sound application of statistics to inspection:

I. The risk of *accepting bad material* is reduced.

II. The risk of *rejecting good material* is reduced.

Many inspection supervisors who have read about quality control have not developed a lively interest in it. The reason for this is that in the conventional presentation of quality control methods, the basic principles are surrounded by a cloak of statistics which repels the so-called practical man.

Returning to the sales formula mentioned previously, the **attention** of the average inspection supervisor is usually easily obtained by a simple demonstration with a deck of playing cards. This demonstration is outlined in the footnote.

Once attention is secured, **interest** in quality control is usually developed by an analysis of the supervisor's inspection plan to indicate the risk involved in using the existing plan.

Finally, the creation of a **desire** by the inspector to use quality control methods frequently results from the development of a carefully detailed plan designed to handle a portion of his inspection work.

Given the attention, interest and desire, **favorable action** generally follows the extension of the detailed plan to the remainder of the inspection supervisor's work.

It is imperative that the sound application of statistics to acceptance inspection be sold from the top of the organization down; all layers of management must be solidly behind the policy.

*These remarks represent the personal views of the author, and should not be interpreted as the official attitude of the Ordnance Dept., U. S. Army.

The same care exercised in selling quality control methods to inspection supervisors must be used with production supervisors. Otherwise sharp differences of opinion may develop between the production and inspection groups which prevent the full utilization of the benefits of quality control methods as applied to both acceptance inspection control and to manufacturing control. You may have occasion to use the following anecdote when such pronounced and seemingly irreconcilable differences of opinion develop between two groups in a single organization:

In the intense production drive before Pearl Harbor, a serious dispute arose between the quality-conscious inspection department and the quantity-minded production department in a newly converted plant. The dispute threatened to halt shipments. The chief inspector was backed up by the chief engineer and the production manager in turn was defended by the plant superintendent. When the vice-president in charge of operations heard about the delay in shipments, he called the heads of the two factions together and told them this story:

"A very serious railroad wreck had occurred in England. Investigation revealed there was only one eye-witness to the tragedy. The witness recalled that he was walking home on a bridge over the railroad at the time of the accident. He stated first he heard a sharp whistle and on looking to the right saw the headlight of a train racing south on track No. 1. A few seconds later he heard a long blast and on looking to the left saw another train speeding north on track No. 1. Horror stricken, he watched the locomotives collide head-on. At this point, the chairman of the investigating committee asked the witness what he thought of the wreck. He replied, 'I thought it was a helluva way to run a railroad!' "

One of the main objections to the application of sound statistics to acceptance inspection is that the inspection supervisor feels his judgment is being replaced by a system he does not understand, and which he feels has no common-sense background. Frequently his pride is injured because he feels he no longer has the opportunity to use his extensive experience, which must be sacrificed to an arbitrary sub-lot size range, sample size, and allowable number of defectives; and that his work has degenerated into the supervision of a number of clerical assignments. Usually he fails to recognize the analogy between scientific sampling and his many attempts to fill a poker-hand, make a point in a dice game, or call the odds at the race track. A good selling job usually removes these objections by obtaining his cooperation in developing the most appropriate inspection plan and in determining how and when the plan can be varied to obtain corrective action when quality changes.

In closing these remarks, I wish to emphasize that every analysis of the "Personal Equation in Inspection" must pass the test of the very vital question, "Will it help win this war?"

Demonstration

An attempt to evaluate the quality of a small lot with a small sample

FROM two straight decks of playing cards, jokers and four aces were removed, leaving 100 cards containing a total of four aces. The 100 cards were assumed to represent 100 articles made from the same material and by the same production process. The four aces were assumed to represent four defective articles.

The problem is to ascertain what is the quality of the lot by inspecting a sample of ten.

The cards or "articles" are shuffled or "mixed" to obtain a random distribution of the aces or "defectives".

A sample of ten articles is withdrawn from the lot of 100, the withdrawal of the articles being performed at random (that is, not from any pre-determined location) and without any knowledge of the location of the defective articles. Consequently, after shuffling, the cards are spread out face down while the sample of ten is withdrawn.

The sample is examined for defectives (aces) and the number of defectives recorded.

The first sample of ten is shuffled with the remaining 90, another sample of ten is withdrawn from the 100, and the number of defectives again recorded. This is repeated until ten samples have been inspected, each containing ten objects selected from the original 100 at random.

After the first sample is drawn and the number of defectives ascertained (0, 1, 2, 3 or 4), the audience is asked "Does this sample represent the quality of the 100 articles?" The same question is asked after inspecting succeeding samples. While up to four defectives *may* be found in any sample, the number of defectives usually found is zero or one. Frequently a member of the audience will remark that the sample does not represent the lot. The audience is told, at an appropriate time, that a sample size of ten is obviously unlikely to reveal reliable information on the quality of a lot of 100; that the ratio of the sample to the lot, commonly called the "percentage of inspection", is not a controlling factor in ascertaining the risk of accepting defective material and the risk of rejecting acceptable material. On the other hand, it is the

numerical sample size for a particular lot quality that determines these risks.

After the sampling demonstration, the following calculations may be performed to show the risk involved in using a sample size of ten to evaluate quality of a lot of 100 containing 4% defectives. The first calculation is intended to show how frequently samples of ten show *no* defectives, when taken from a lot of 100 containing four defectives.

$$\frac{96}{100}\cdot\frac{95}{99}\cdot\frac{94}{98}\cdot\frac{93}{97}\cdot\frac{92}{96}\cdot\frac{91}{95}\cdot\frac{90}{94}\cdot\frac{89}{93}\cdot\frac{88}{92}\cdot\frac{87}{91} = 0.65$$

This means that, on the average, 65 out of 100 samples of ten each will show no defectives when taken from 100 lots containing 4% defectives in each lot.

The second calculation shows how frequently samples of ten will show one or more defectives when taken from a lot of 100 containing four defectives:

$$1 - 0.65 = 0.35$$

This means that, on the average, 35 samples of ten each will show one or more defectives in each sample when taken from 100 lots containing 4% defectives in each.

Attention of the audience is then directed to the 0.65 chance or probability, which is the result of multiplying a series of fractions, each being higher than 0.95. If the sample were sufficiently increased in size, the result of the similar multiplication would be very small; correspondingly, when this smaller result is subtracted from one, the chance of finding one or more defectives in the sample is very high. (To demonstrate this, it is only necessary to repeat the experiment drawing 60 cards for each sample, instead of ten.) This, then, is the reason for a large sample, independent of the lot size.

Acceptance Control — Not How Much Inspection, But How Good

By L. E. Ekholm
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DURING the past two years, industry has been called on continuously to increase production. This increase has been accomplished despite the fact that specifications for materials have been changed and despite the fact that it has been necessary to educate a large part of the personnel both in production and inspection. In order to increase production on items which were very often entirely unfamiliar, and in order to deliver material which was satisfactory for the end-use intended, large inspection departments have been developed. It was often necessary to inspect in great detail and very often the inspection has become cumbersome. This period might be called the "how much" period.

We are now slowly entering a period where production schedules are, in a large number of instances, practically constant and specifications are more or less stabilized. In place of the original urge for continuously increased production, the philosophy has been developing as to how good the raw materials and the finished products can be made. This is the period which we might call the "how good" period. This philosophy in itself is admirable, inasmuch as every manufacturer certainly wants to increase the quality of his products, and certainly nothing but the best should be given our fighting forces.

We believe that *specification* requirements of all raw materials and equipment should be based on their final *service* requirements; therefore, the inspection and testing procedures should definitely be the results of service experience. There are undoubtedly times when service shows that requirements must be raised — for example, tolerances must be narrowed, steel must be cleaner, or impact values must be raised. This should be no reason, however, that *all* steel quality factors must be more restricted, nor that *all* manufacturing tolerances and *all* manufacturing quality factors must be made more restrictive.

We know from experience that when materials become more plentiful, the natural tendency is to demand increased quality and to place more restrictions on purchased materials and products. We all saw this happen during the leaner years of the 1930's, when high quality materials were often used unnecessarily. It is dangerous to give this natural tendency too much freedom, inasmuch as materials are not so plentiful as to allow us to waste them.

The above two reasons for increasing quality — that is, the dictates of service requirements and surplus of materials — are understandable and appreciated. There are times, however, when requirements are raised for no apparent reason except the dictates of some purchaser's mind. This reason is not understandable and should be closely controlled because it is likely to be very dangerous. We feel that, before specifications are made more restrictive, these restrictions should be studied to determine whether *service* actually requires them or whether they are being added unnecessarily.

Quality can, however, be raised. This can easily be accomplished by understanding the

fundamentals of acceptance control or inspection.

The fundamental purpose of an internal inspection department, as well as a so-called foreign inspection department, is not to throw out bad material. Whoever uses an inspection department primarily for this purpose loses much valuable material and data. It is our contention that the fundamental reason for inspection is to record results and assist in analyzing these results in order to raise the general quality level of the objects being produced.

Value of Higher Quality Levels

By means of the experiences and data obtained through scientific inspection procedures, it is possible by increasing quality levels to accomplish the following:

1. Increase production with present production manpower and machines.
2. Reduce inspection forces.
3. Waste less material.

It is of utmost importance that supervisors and individual inspectors be educated about the true meaning and reasons for inspection and inspection results. The individual inspector can make scientific acceptance procedures a success and can be a tremendous reservoir of data on acceptance results if he is properly informed. He can also, if properly directed, take acceptance procedures out of the category of "how much" inspection into the category of "how good" inspection.

Because production schedules are not at present rapidly increasing, except in isolated instances, and since specifications are more or less standardized, now is the time to develop scientific inspection methods, making full use of the past data on acceptances and rejections and the variables pertaining thereto. In this way, acceptance procedures based on results can be put into force, thereby lot inspections can be made with security; likewise other methods can be introduced whereby inspection can be expedited with resultant reduction in inspection forces.

It seems that we can reach that happy end point which gives the best material most economically by:

1. Engineering departments and specification writers weighing all quality restrictions that are added to the present specifications in order that any newly added restrictions be dictated by service results only.
2. Keeping accurate records on inspection results in order that procedures can be established on a scientific basis, thereby reducing the amount of actual inspection necessary, still maintaining quality. The greatest reason for this, however, is increasing the general quality level.
3. Instructing inspection bureaus, especially individual inspectors, with the true meaning of inspection in order that their time and efforts are placed on the factors that are of most importance. This will give them confidence that in the acceptance of products these products will give the service required of them.

Gaging Bearing Races at Timken Roller Bearing Co.

B—Considerations Having to Do With the Method of Inspection

Precision Measurements

By John A. Harrington
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THE APPRECIATION and the growing use of more precise measurements in industry have generally followed a fairly uniform pattern.

At the beginning, when the length of a hand or arm or foot was the unit of measurement, these units served their purpose until such a time as the necessity for an agreement among the various peoples arose for a uniform yard or foot, so that the traders and merchants would be able to buy and sell from the same unit in different parts of the country. This necessitated a standard unit, located at some central point so that it might be referred to readily. But as commerce and industry grew and expanded it became increasingly difficult for all peoples concerned to make long trips to check their measurements against the standards. Eventually there were devised more precise methods, such as rulers and other measuring devices, which were sufficiently accurate for the measurements of this later period, and helped in maintaining more accurate dimensions.

During World War I it was found that finer measurements, which adhered more closely to the standard dimensions, were necessary, and there was an attempt made to produce a greater number of accurate standards so that they might be distributed more widely and thereby be made more available to the industries. It was found at that time that while most factories were capable of producing excellent work, it was extremely difficult to get interchangeability of parts because few plants had accurate standards for comparison. It was seldom that parts made in different plants and shipped to the battle fronts would be interchangeable with the parts previously used. To correct this situation, the National Bureau of Standards, under the guidance of Maj. W. F. Hoke of the gage division, produced about 200 sets of accurate gage blocks, whose tolerances were within a few millionths of an inch. These were distributed to the various arsenals and inspection centers, but reached them so late that they had very little influence on the mass interchangeability necessary. As a result most parts made during the 1914-1918 emergency had to be selected or hand fitted if c tolerances were necessary.

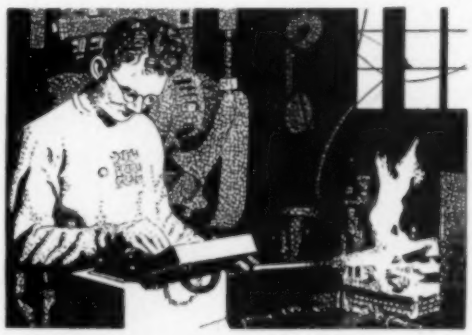
Since World War I the a motive industry, and more p ticularly the airplane indust has proven that finer finish and closer tolerances not o increase the life of a machi but also increase its efficien This meant that closer dim sions would have to be specif if interchangeability was to maintained on a producti basis. In order to accompli this it was obvious that precise standards wo have to be available, not only at convenient poi throughout the country but also that these sta ards would have to be located in each plant a often in various parts of the same plant.

The only accurate standards that had b developed in the 1920's that were convenient f plant use were the precision gage blocks som times called "Jo Blocks", and which now are general use throughout the world. By using th precise measuring instruments the manufactur has what we might call the exact "inch" that used by all other manufacturers in all parts the world, and by reference to these standa blocks he can produce, within a few millionth any dimension his parts call for with the assu ance that it will not only pass the close inspecti of his customer but that it will also be inte changeable with a similar part made with th same precision in any part of the world.

The accuracy of the dimensions built in the gage block is assured by its comparison wi the number of monochromatic light waves in standard inch, and since light waves are th same in all parts of the world, and since th standardizing authorities in all civilized countri have agreed upon the number of light waves i the standard "inch", it is readily possible for th gage block manufacturer to produce these fi measuring standards to accuracies of a few mi lionths of an inch. The importance of thes accurate dimensions is readily appreciated whe we find that some of the limits permitted o airplane instrument parts are only 25 millionth of an inch (a quarter of a ten-thousandth). Th means that gages made to inspect these part should be accurate to within 2½ or 3 millionth

When industry recognized the necessity for these close dimensions, it was presented with some additional problems which in many cases have not been given as much consideration as they deserve. For instance, mass production of truly interchangeable parts now requires more accurately built and more rigid machinery than was necessary in the past. It also requires a better equipped and trained inspection department. But probably of equal importance is the problem of stability, not only in the gages used for inspection purposes but also stability *in the finished part itself*. This seems to be a problem primarily for the metallurgist, for it is necessary for him to develop not only the metal best suited for the physicals needed in the part, but also one that is stable and will maintain its size throughout the life of the part. It will also be necessary for him to develop heat treating methods necessary for stability and spread information about them among the manufacturers. It does little good to machine and finish an accurate spool for a valve for some of the hydraulic equipment in an airplane, where limits of ± ½ of one ten-thousandth are specified, only to find that after 30 or 90 days the piece has grown or shrunk as much as 1½ ten-thousandths! Or, as another example, to make up, we will say, an accurate snap gage and find that it has changed dimensions even while lying on the shelf in the inspection department.

The National Bureau of Standards has set up a test for stability of gage blocks which might be used by the manufacturers of interchangeable parts. The test consists of boiling the finished piece for 24 hr. in a 1% solution of potassium dichromate and water. If the piece has changed dimension by more than 2 millionths of an inch after this treatment it is not considered stable or likely to hold its proper size.



Gage blocks can be used by themselves for accurate measurements, but, like any other tool, their usefulness is greatly enhanced if they are used in conjunction with proper instruments or fixtures. We might cite as an example an actual case such as the valve spool mentioned before. The production run on this part called for 5000 units. There was required a working gage and an inspection gage for each of three dimensions, or a total of six snap gages each of which had to be finished to accurate "go" and "no-go" dimensions having a tolerance of 25 millionths. It was established that it would take the tool room at least 60 man-hours to produce these gages at an estimated cost of $180. It was found that by using a set of working gage blocks, together with the instruments supplied by the gage block manufacturer, these gages could be made up in about 15 min. and would be more accurate than those made by the tool room. Also, the caliper jaws used in making up these gages had a life far in excess of 5000 parts, but had they been worn out their replacement value would have been $78. In this case there was an estimated saving of $102 together with 60 man-hours in the tool room that could be used for other purposes.

This illustration is given to show the savings and increased accuracy accruing from the more frequent use of modern precision measuring instruments. In order to maintain the accuracy of these gage blocks and instruments there is supplied with the modern sets a monochromatic light and quartz optical flats. These two instruments enable the inspector to check pieces of almost any shape for flatness or dimension. By using the optical flats and gage blocks, he can read the dimension of a sphere (such as a ball bearing), a cylinder (such as a plug gage), or he can read, with thread pins, the pitch diameter of thread gages.

Probably the most important use of the optical flats is for checking the dimension and flatness of the gage blocks themselves. Instead of sending the blocks back to the manufacturer or the United States Bureau of Standards for frequent recalibration, the inspector can do this work himself at shorter intervals. Flatness of many other parts, such as anvils, micrometers, comparators, and lap-surfaces of any kind, can be easily checked by this same procedure.

The principles of precision measurement are simple and can be readily understood by almost anyone when they are brought to his attention. Quality control has now become one of the permanent and necessary departments of industry and, since the foundation upon which dimensional quality control is built is the precision gage block, the sooner each of us becomes familiar with its use and has a more thorough understanding of the methods employed to ensure its accuracy, the sooner industry will enjoy the benefits to be derived.

Control Charts

By C. S. Gotwals
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QUALITY CONTROL, the topic of this series of papers, must be regarded as a management tool that aids in the manufacture of products that meet engineering specifications. Statistical analysis of inspection results and the use of control charts — the topic of my individual assignment — has been used by SKF Industries, Inc., for a long enough time to prove to us that the quality of the product improves even with less inspection, decreases the amount of rejects by keeping at a safer distance from drawing tolerance, gives early warning of changed manufacturing conditions, and provides a means for setting tolerances with regard to economy of manufacture.

Quality, however, must be built into the product. No amount of inspection nor any function of quality control will in itself improve the quality. Inspectors and quality control engineers are what the accountant knows as "expense" and must justify their existence since they actually make nothing. All such people, as a general rule, are listed as "non-productive".

Inspection too frequently has been merely the sorting of good from bad pieces; in most such cases very little investigation has been done as to the real reason for bad pieces. Just report the results of inspection to the production foreman and rely on his correcting the trouble in the future! Many times it would be true that the basic trouble was in a previous operation, and the production foreman would not be able to do much about it.

It is, of course, recognized that pieces cannot be made exactly alike, due to lack of uniformity in the material, variations in skill of operators, machine variability, wear of gages, and so on. Perfection is impossible. Quality control, by the elimination of assignable causes, is the effort to approach this ideal.

Let us consider one of the items just mentioned, namely, variability of operators — either man to man, or variability in performance of a single operator, day to day or even hour to hour. A few of the causes of such variability may be:

1. Lack of understanding of the requirements, either as to the correct finish or the size tolerances.

2. Variation in skill. (Coordination depends upon the operator's physical condition, and "off days" are certain to occur.)

3. Variation in attention. Some operators suffer more than others from any monotonous job; others are temperamental day dreamers.

4. "Attitude", ranging from the feeling that all that is necessary is to just "get by", to the eager desire to excel and be promoted to a better rate or a more important post.

Any control method must obviously have the ability to distinguish quickly whether unacceptable parts are due to a sub-standard operator or a mal-functioning machine. Let's take a case — for example the simple operation of centering spherical rollers:

In the grinding of rollers for spherical bearings it is necessary to have a center hole in one end of the roller. This is done on a Bliss vertical punch press before the roller is hardened. This hole has a tolerance of 0.0025 in. off center, or 0.005 in. eccentric with O.D. (indicator reading). The other end of the roller is not centered. In the grinding operation the roller is supported by a dead center in the countersunk hole on the one end, and a cup arrangement as a live center on the other end; thus, excessive eccentricity of the center hole or countersunk hole will cause the greater portion of stock to be removed from one side of the roller and leave the machined surface (called "black") not "cleaned up" on the other side. This roller is then scrap or must be re-operated to a smaller diameter, which is not desirable.

Examination of the daily and weekly scrap and re-operation records, together with the control reports, indicated a gradual upward trend in scrap rollers. The rollers were checked to determine if the correct amount of stock was being allowed in machining, and this was found to be within tolerance. The end grinding operations were checked to determine if an out-of-square condition was present. This did not seem to be the cause. Thus, by simple elimination of possible assignable causes, we had left only the eccentricity of the center to investigate.

Small distributional measurements were made in the machining division of lots of rollers. The mean eccentricity of the center hole proved to be about 0.004 in., the extremes of the pattern extending to about 0.007 in. This extreme variability was not apparent in all lots, and observations seemed to indicate that only one machine was producing to this pattern.

Control charts were placed on each of the three machines producing this work, as this appeared to be the quickest and easiest way to

find out where the trouble was occurring. Control chart procedure is as follows:

Averages of five pieces were plotted on an "average and range" chart every 15 min. on the three presses. Control limits were established after about six hours' study, which gave us about 25 readings, and experience has shown that 25 sub-groups of five pieces each is enough evidence to establish our limit lines.

(It is sometimes necessary to accept the hazard of making tentative predictions when sampling is expensive, or when further sampling becomes impossible because of the need for a quick answer. Under such circumstances the inference, of course, becomes more a matter of engineering judgment and less a matter of statistical analysis. When offering tentative predictions based on scant data, one recalls the story of the man who went into a restaurant and asked for toast, coffee and a soft boiled egg. "Would you like anything else?" the waitress asked. "Yes," answered the man, "A few kind words." As the waitress silently started to leave, the man asked, "How about the few kind words?" She leaned over and whispered, "Don't eat the egg!" So, without proper tempering of statistical data with engineering judgment, we may get a bad egg at times!)

The analysis of our three charts showed us that we did have trouble. Two machines did not have any points outside of the control limits, indicating that they were operating to a controlled pattern and within limits. The third chart clearly showed points outside of the control limits and therefore no reliable prediction could be made of this machine; in other words, it might suddenly get a number of bad pieces and just as suddenly produce good parts. The floor inspector or even the operator may not notice or catch the deviation.

The action taken in this instance was to study the machine. It was found that the indexing plate on the press was loose and the centering bell slightly ridged. These were quickly corrected and then the punch life was studied, leading to a slight alteration in its angle.

It was by working toward the normal with control limits on both sides, instead of working to keep within engineering limits, that we find the pieces actually coming well within specification, on the average. A greater percentage of pieces is at normal and therefore the quality level becomes better.*

This leads to the problem of sampling for inspection.

The first requirement is to obtain a representative or random sample. The mathematics involved in determining size of sample and number of rejects permissible to guarantee a certain level of quality will not be discussed here. Doctor Sullivan has already indicated in his discussion how the sizes are arrived at; the actual figures can be found in the Dodge Romig or Ordnance Sampling Tables.

The important thing is to get a *random* sample. If by the nature of the process, such as in ball or roller manufacture, the pieces are thoroughly mixed by tumbling, then it is not difficult to get a random sample. Otherwise it is necessary to gather the sample from all parts of the container.

Having obtained a random sample and having given it careful inspection the results are recorded. These statistics are collected and analyzed by the quality control inspector, and reports made weekly to the production department and monthly to management. These reports reflect the trend of the quality by departments and action is taken by the production department to bring quality back into control if, as and when necessary. If a department is out of control for several weeks, this is reflected in the inspection costs being charged against that department.

In our organization it is the responsibility of the manufacturing department to keep the

*EDITOR'S FOOTNOTE — Another speaker at this group meeting called attention to the use of control charts for maintaining uniformity, heat to heat, in a large and modern steel mill.

The main procedure involves analyzing acceptance data so as to reveal erratic practices in the mills which might cause regularly recurring defects. The direct result of such analyses and the consequent investigations are process control charts which are prominently displayed at the various control stations within the mill. These charts are not then forgotten, but become a dynamic working part of mill practice. Metallurgists police the use of the control chart and see that they are understood and used properly; at the same time the metallurgists and the inspection department are constantly making further analyses and investigations so that the process chart may be brought up to date when revisions are indicated. This practice is not only an effective substitute in times of manpower shortage, but is also likely to become a permanent feature of steel mill practice, since it correlates specifications and inspection procedures with the mill practices, which in the final analysis actually determine whether or not the specifications will be met. Such a correlation not only saves valuable time, material, and facilities, but also tends to raise the quality level without restricting specifications, and alleviates conditions arising from the present shortage of skilled metallurgists and metallurgical observers.

operation in control, although in these days of many new untrained operators we sometimes find it necessary to supplement this by having quality control inspectors go into those departments for varying periods.

To help keep *operators* in control, we find it very desirable to keep gages and gage equipment under control. By this I mean that we again keep records of the measurements of gages and of master rods and disks. A system has been installed whereby the history of each gage is recorded on a separate card and numbered for identification. A gage checker with a cart containing measuring equipment goes into every department, checking each gage on the floor and recording any change. Repairs are taken care of promptly, and abuse of gaging equipment can be promptly noted and corrected. This statistical information is quite helpful to settle that old shop question, "When did you have the Master checked?"

Other uses of the gage records are to tell how frequently it is necessary to check each type of gage and whether excessive wear on some part of the gage may make a redesign desirable. Only accurate statistics can determine this point with any degree of satisfaction.

After the operators and the gages, then the inspectors. It is one thing to know that gages are accurate, but another to insure that the inspectors use them properly. Such is not always true. Inspectors are careless; they day-dream; they also have off-days. Checking by limit gages consists of very simple operations, and the inspector may succumb to monotony, let his attention wander, and literally get into a rut. The result is a certain percentage distribution between accepted and rejected parts, regardless of the actual distribution; he automatically or instinctively throws out one every so often. It is therefore important to get a random inspection of the inspectors' work (without advance notice, of course). Samples are taken and a record kept of the number of errors found. This forms a basis for selection and promotion or training, and perhaps even a transfer to another department. Naturally the inspector of inspectors must be a man of high reliability and responsibility.

It still must be remembered, however, that quality as such must be built into the product by the production men, and no amount of inspection or statistics will make the parts any better. Analyzing statistics merely aids the production men to get quality under control.

A lot has been written technically about quality control — in fact, I think it has been oversold in that regard. That is the reason so many industrial managements did not initiate statistical analysis and control chart techniques long ago. You know we are all afraid only of those things which we don't understand. I have tried to point out that in reality it is a very simple and understandable tool.

If any of you are considering the installation of a quality control division, using statistical analysis, you will have a difficult time without the full support and working knowledge of top management. Foremen and inspector supervisors must be sold, and the fear of the terms "control chart" and "statistical analysis" must be allayed.

A Specific Application of Quality Control

THE AMMUNITION BRANCH of the Ordnance Department began to consider the application of statistical quality control methods to acceptance inspection toward the end of 1941. Of course, there had been inspection and acceptance of ammunition long before that, but the application of quality control methods resulted in very important changes.

A sharp distinction should be made between two *types* of inspection. The primary *purpose* of all inspection is, of course, that of determining or measuring quality. In some instances, quality is measured in order to control and correct the process of manufacture; let us call that "process inspection". In other instances, quality is measured in order to determine whether material is acceptable; call that "acceptance inspection".

There is a tremendous difference in methods between process and acceptance inspection. In **process inspection,** the inspector is logically placed within the production line. He inspects material as it comes off machines, and when he finds trouble, corrections are made in the machines. Where material is processed through several successive operations, the inspector inspects between these operations, because one of his functions is to prevent the waste of unnecessary processing of defective material. In a sense, the inspector is as much a part of the manufacturing process as any one of the machines. His inspection is one of the operations through which every piece must flow before it is completed, and if his inspection

is properly performed, the final product will meet all specifications and will therefore be acceptable.

Now the purpose of **acceptance inspection** is that of determining whether the final product does meet the specification and is acceptable. If a process inspection, such as was just described, will ensure specified quality, then such a process inspection will accomplish the purpose of acceptance inspection. But when we use process inspection to determine acceptability we introduce certain difficulties which make it thoroughly undesirable.

The Ordnance Department is a consumer. It prepares designs, writes specifications, and contracts with private industry to manufacture to these specifications. It has only one desire, and that is that the material which it buys shall meet the specifications that it has written. It takes considerable engineering knowledge to write logical specifications. For example, if you specify dimensions, the kind of material, and the final strength, you may easily find that you have written a specification which is impossible. The dimensions and material you have specified may result in a strength different from that which you require. You have here specified methods (that is, dimensions and materials) and also results (that is, strength). If your methods are not compatible with the results you want, your specification is impossible. The Ordnance Department recognizes the distinction between methods and results in writing specifications. If it specifies methods of manufacture, it must accept whatever is produced; if it specifies desired results, it must allow the manufacturer to use whatever methods he finds necessary.

The separation of methods and results is directly applicable to acceptance inspection. If you perform process inspection, your inspector is on part of the methods, and you must accept the results, whether they be good or bad. If it is only results that matter, then your inspector may not perform process inspection. Good acceptance inspection consists in allowing the manufacturer to use whatever methods of process inspection he finds necessary, and in restricting the acceptance inspection to examination of the final product for conformance to specifications.

In applying quality control to acceptance inspection, the Ammunition Branch of the Ordnance Department has recognized this essential point. Its inspectors have been told that it is not their function to perform process inspection. Their function is only that of examining the finished product, of accepting it if it is acceptable, and of rejecting it if it is defective.

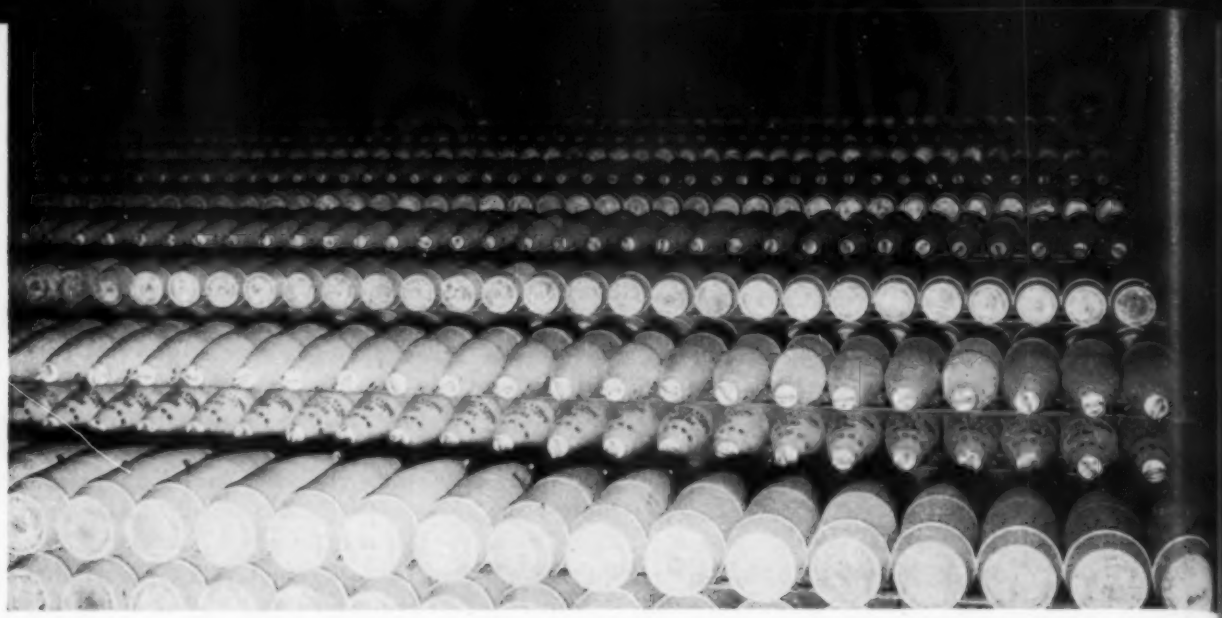
Reactions of manufacturers to this policy have been varied. Those manufacturers who knew enough about inspection to do it for themselves were delighted to get the government men out of their production lines. Those manufacturers who were afraid to do their own inspection — and there were a very large number of these — were unhappy.

If we accept as a basic fact that acceptance inspection must be restricted to examining a finished product, then we must ask how such inspection can control quality. An acceptance inspector can do only one of two things: He can accept or he can reject. If he accepts, then quality is obviously satisfactory. If he rejects, quality is not satisfactory. From the consumer's point of view, control of quality is completely obtained by accepting good material and rejecting bad material. From the producer's point of view, quality is controlled by economic pressure — when the acceptance inspector begins rejecting material, the manufacturer must improve his quality or lose his shirt.

The distinction between process inspection and acceptance inspection is too frequently not recognized, and yet recognition of the distinction is essential in developing a consistent plan of acceptance inspection. There are, of course, other considerations that will influence the final plan. In problems faced by the Ammunition Branch, for example, we start with the knowledge that inspection will be performed on a finished product. Usually the product will consist of a large number of fairly small parts. 100% inspection is undesirable because it is really a form of process inspection. Acceptable material must be reasonably close to specifications. The phrase "reasonably close" is somewhat loose; it must always be carefully defined. Suppose the specification is entirely dimensional; then "reasonably close" might mean that all but 1 or 2% of the pieces shall conform to the specification. The

Acceptance Inspection of Ammunition

By H. R. Bellinson
Chief, Quality Control Unit
Ordnance Department
Ammunition Branch



purpose of acceptance inspection would then be to determine whether the number of non-conforming pieces exceeded the allowable percentage.

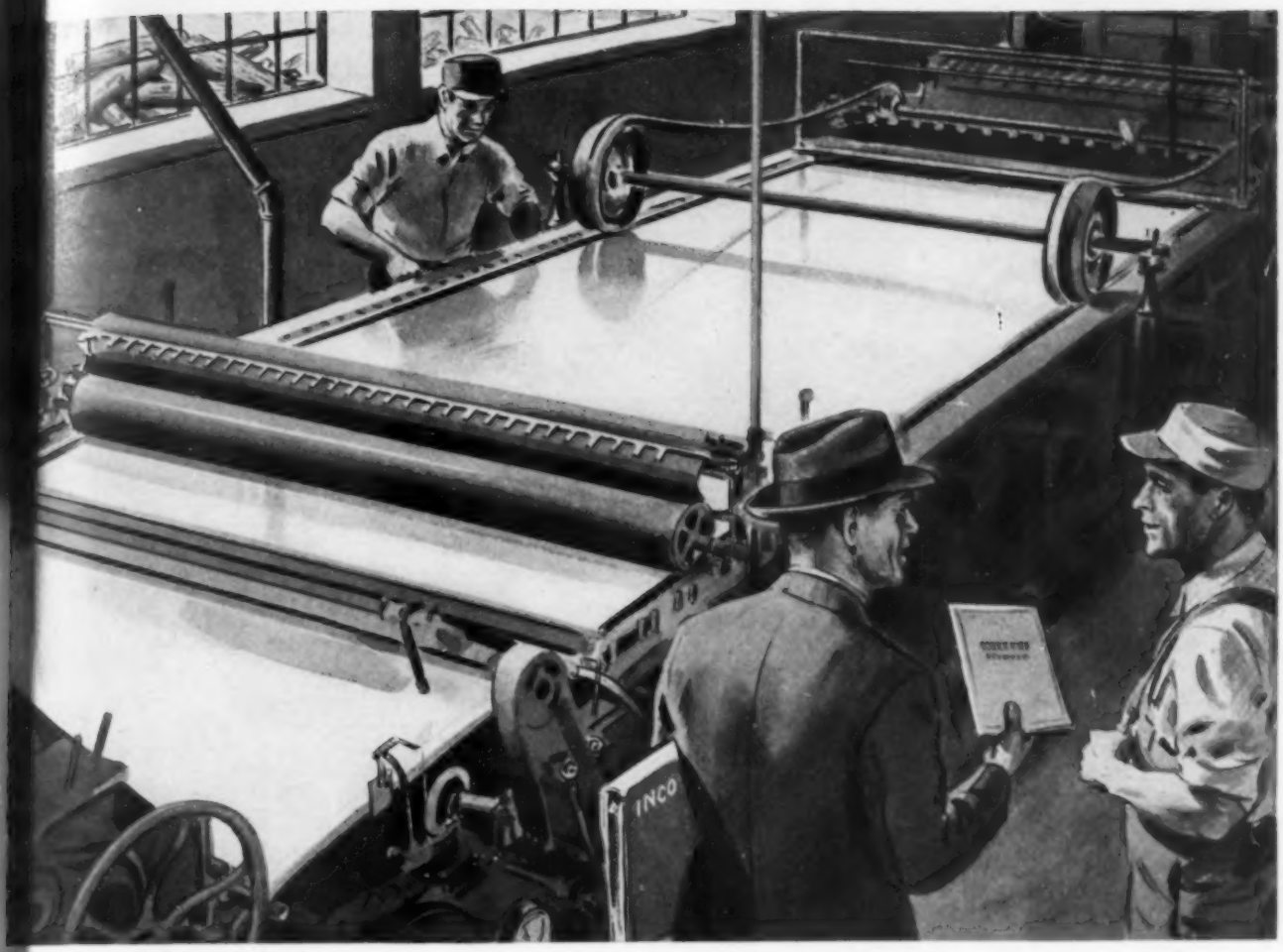
Perhaps the first thing a student of quality control learns is that a small sample will not determine whether material is better or worse than a high quality. A sample of 10 pieces might tell whether the material is better than 10% bad, but obviously is worthless when it is important to detect 2% bad. To meet the requirements for sensitivity in acceptance inspection, samples of perhaps 100 pieces, preferably more, must be used, and if inspection is to be economical, then the sample must be selected from a lot of several thousand pieces. There is only one other factor: If a plan is to be used generally, it must be adaptable enough to fit everywhere.

These considerations, as interpreted by the Ammunition Branch, have resulted in a plan of inspection which can be outlined in fairly simple terms: The flow of production is divided into convenient lots for purposes of inspection and acceptance. The lot may contain as few as 500 pieces, or may reach a million. From each lot, a sample is selected whose size is related to the size of the lot. Sample sizes range from 50 for a lot of 500 to 500 pieces for a lot of one million. Each piece in the sample is inspected for each of a considerable number of defects. These defects have all been listed in advance, and are, of cours related to the specification. If a piece contai any defect, it is considered defective. The nu ber of defective pieces in the sample is dete mined. If the number of defectives does n exceed a predetermined acceptance number, th lot is accepted; if the number of defectives do exceed the acceptance number, the entire lot rejected. The acceptance numbers are obtain from a table issued by the Ordnance Departme which gives them as functions of the sample si and of an "acceptable quality level". This accep able quality level represents the worst quali which it is desired to accept consistently witho rejection.*

There are a few added attractions to th plan. For example, if a manufacturer consis ently produces material better than the acceptab quality, it becomes possible to reduce inspectio If a manufacturer consistently produces materi worse than the acceptable quality, inspectio becomes more severe, in order to reduce the ris that defective material may be accepted throug the laws of probability.

The important thing in this plan of accep ance inspection is that it accepts and rejects i large quantities. It is always an entire lot whic is accepted or rejected. Choice of a large lot i necessary in order to be able to select a larg sample, which in turn is necessary to measur quality accurately. But choice of a large lot als means that the manufacturer feels a rejectio where it hurts most, and takes immediate actio to prevent so sad a thing from happening again This may sound tough, but remember that th inspector does not produce quality, he merely determines whether it is already there or not and the only means he has of controlling quality is that of rejection. If this method of control is to be made effective, then rejections must be made in a manner which produces results!

*Editor's Footnote — It was brought out in discussion that where difficulty had been experienced in applying statistical quality control, it was on those contracts where abnormally large percentages of rejects were obtained even with the previous methods of inspection. In those plants where production had previously been brought under control, no difficulty was experienced. It should be pointed out that the method described by Mr. Bellinson as applied by the Ammunition Branch could more aptly be called "statistical acceptance inspection", inasmuch as the usual control over the process is not attempted. In other words, it is acceptance inspection by sampling rather than by 100% gage checking.



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Method of Identification of Inclusions in Iron and Steel

Originated by Wm. Campbell and G. F. Comstock (Proc. A.S.T.M., Vol. 23, p. 521) and Modified by C. R. Wohrman, Merrill Scheil and Miss M. Baeyertz

Polish Specimen Carefully so as to Preserve Inclusions and Project Magnified Image on Ground Glass by Arc or Equally White Light Without Color Screen

Gray or Black Inclusions

Etch 10 sec. with 10% nitric acid in alcohol

Strongly Attacked
LIME COMPOUND *from mold wash (rare)*

Unattacked
Etch 5 min. with 10% chromic acid in water (Be careful to observe that the polished surface is wetted by the solution)

Weakly Attacked *(slightly pitted or darkened)*
COMPOUND OXIDE: *(a) either* FeO *with* FeS *in solution (usually accompanied by* FeO-FeS EUTECTIC*), or (b)* FeO+MnO *and other* OXIDES *in solution*
Note 1: Octahedral crystals are probably MAGNETITE.
Note 2: Both (a) and (b) will be darkened further by 20 sec. sulphur printing (2% H_2SO_4 *in water) and destroyed by etching with stannous chloride as indicated below*

Attacked
FeS-MnS, *rich in* MnS. *Note: Reaction not always decisive. Any unattacked* FeS-MnS *will be blackened by next treatment*

Completely Blackened
(1)* FeS-MnS, MnS *below 50%*
(2)* FeS-MnS, MnS *above 50% or* OXIDE *very rich in* MnO
** Refer to color before etch*

Partly Attacked
(a) OXIDE *rich in* MnO *(will be destroyed by stannous chloride)*
(b) SILICATE *with some* MnO *(will be destroyed by hydrofluoric acid)*

Attacked
IRON OXIDE *or (if previously pitted)* COMPOUND OXIDE

Attacked
SILICATE *(if previously pitted presence of* Mn *is indicated)*

If fine particles, very dark color, difficult to polish without pitting and not elongated by hot work is ALUMINA

Fairly large angular fragments, showing changeable bright spots as focus is changed, are SAND GRAINS *(in steel castings)*

Inclusions of Warm Colors

Etch 10 min. with boiling alkaline sodium picrate

Attacked
IRON SULPHIDE *(pale yellowish)*

Unattacked

Etch 10 min. in 20% aqueous solution of HF

Attacked: *Removes* ZIRCONIUM NITRIDE *(yellow cubes) and* ZIRCONIUM SULPHIDE *(tan crystals)*

Unattacked *Inclusions in high chromium steels*

Etch 5 min. in boiling 10% H_2SO_4 + 1% $KMnO_4$, & lightly repolish*

Unattacked
CHROMIUM OXIDE *(purplish gray by reflected light, bright green by transmitted light)*
TITANIUM NITRIDE *(yellow cubes)*
TITANIUM CYANO-NITRIDE *(pinkish; strongly angular, easily pitted in polishing)*

Attacked
CHROMITE Cr_2O_3·FeO, *isotropic; red to brown by transmitted light*

Unattacked
Note color: (1) Very faint pale gray, (2) Medium or dark grey, and etch 5 min. with boiling alkaline sodium picrate

Partly Attacked
(or partly attacked in previous treatments) etch 10 min. with a saturated solution of stannous chloride in alcohol

Unattacked
(or previously pitted) etch 10 min. with 20% aqueous solution of hydrofluoric acid.

Unattacked
Repolish and note color and form

If color not especially dark, easily polished smooth without pitting

Small angular particles, bluish in color probably TITANIUM OXIDE *(in titanium treated steels)*

* *Note: Suitable only for stainless steels with clean (unoxidized) surfaces.*

Supplementary Tests

In all instances check determinations in the light of the evidence of a careful chemical analysis, and, whenever possible, by other methods, such as:

I Sulphur Printing

(for 20 sec. using a 2% aqueous solution of H_2SO_4*)*
(1) Dissolves all FeS-MnS *inclusions*
(2) Partly dissolves (pits) FeO *containing* FeS *and* OXIDES *of other metals in solution*
(3) Leaves unchanged: IRON SULPHIDE *(pale yellow), pure* IRON OXIDE *(medium grey),* SILICATES *(dark grey)*

II Matweieff's Tests

(a) Dilute tartaric acid does not attack OXIDES *or* SILICATES, *but colors* MnS *lightly and* FeS *decidedly*
(b) Heat sample in hydrogen at 1600°F., OXIDES *are reduced,* SILICATES *and* SULPHIDES *are unaffected*
(c) Repolish (b), etch with dilute $FeCl_3$ *in alcohol; if reduced oxide particles are colored deeply they contain some* Mn

III Rohl's Test for Sulphides

Short etch with 1% picric acid in alcohol, then temper to dark yellow. FeS *turns dark blue to reddish violet, and* MnS *turns dull grey to bright white.*

This department, "Bits and Pieces", welcomes notes concerning new ways of doing things to metals, either in shop or laboratory. An ⊜ book of your choosing (other than the Metals Handbook) is the reward for a publishable item

Bits and Pieces

Metallurgicus' Own Pages

Cycle Annealing

IT HAS LONG BEEN RECOGNIZED by most metallurgists that annealing of steel is an operation which is simple in principle and complex in practice. To get uniformity of hardness and structure throughout one furnace charge, and to get even approximately similar results heat-to-heat of the same type of steel, requires careful control of such factors as maximum temperature, time at heat, rate of cooling, and temperature of discharge from the furnace. With conventional "full annealing" the time required for many alloy steels is very long and final hardness is often too variable for production machining.

There is no need for discussing the best structure or hardness for high machinability, but it is generally realized that minimum hardness is usually *not* best, and that variation in hardness and structure from one piece to the next is the worst factor interfering with economical and efficient machining schedules.

For this reason the larger, better-equipped production shops, such as in the automotive industry, have for many years used "cycle annealing" rather than full annealing, because of the shorter time required and — more important — the better uniformity and quality of microstructure, with consequent better machining.

The literature on "cycle annealing" is scanty; a search through the index of "Metals Handbook" reveals no such subject, neither do the articles on "Principles of Heat Treatment of Iron and Steel" and "Heat Treatment of Metal" remark thereon. Infrequent references to annealing cycles occur in the technical press, usually without particular details, but quite recently Peter Payson of Crucible Steel Co. of America, in an excellent series of articles in *The Iron Age* in June and July 1943 on "The Annealing of Steel"* has thrown new and revealing light on cycle annealing. Those who are interested in this subject — and anyone using steels whose machining is a problem ought to be interested — should read this excellent dissertation.

Since Payson has done such a thorough job of discussing the *principles* of annealing, there is no justification for an attempt to summarize or repeat here. Let it suffice to say that cycle annealing is annealing done by a controlled and specified cycle of time and temperature, involving heating to a chosen initial (austenizing) temperature, followed by rapid cooling to a selected lower temperature near the "knee of the S-curve"† where pearlite forms on isothermal transformation, holding at this temperature long enough for transformation to complete, and then cooling by any convenient means. Since the "annealing" is done at constant temperature, section effects are reduced, uniformity improved, and the structures are usually more desirable for machining than those produced by "full anneal-

*Also available from Crucible Steel Co. of America, 405 Lexington Ave., New York 20, N. Y., in reprint form at $1.00.

†Payson prefers to call them "TTT curves" (time-temperature-transformation) which is appealing, with all respect to Bain, Davenport, et al., who originated the "S-curves", because they are only shaped like an S for simple steels — and even then the bottom of the S is horizontal and multiple. By the way, I am more than enthusiastic about the "Atlas of Isothermal Transformation Diagrams" recently published by United States Steel Corp. — 56 complete diagrams for 47 different compositions.

ing" in the old way which includes slow cooling in the furnace.

Perhaps this is a good time to pause for a month in this general discussion, and permit all of you to read Payson's series of articles, and then when we re-convene we will consider ways and means of doing cycle annealing with available equipment.

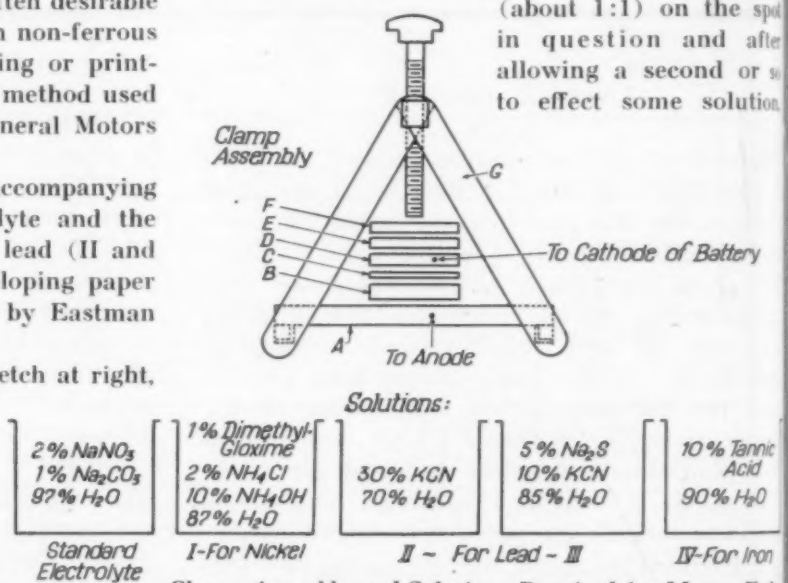
METALLURGICUS

Spot Tests for Non-Ferrous Alloys

OCTOBER'S *Metal Progress* carried a request for spot tests for brasses and bronzes, to detect incidental elements, or even estimate the tin content. Possibly what was wanted was some simple way to distinguish alloys of identical color and hardness. On the other hand it is often desirable to locate and identify segregations in non-ferrous bearings or castings by macro-etching or printing, and the following describes the method used for iron, lead and nickel in the General Motors Diesel Laboratories:

Reagents Required — The accompanying sketch shows the standard electrolyte and the developing solutions for nickel (I), lead (II and III), and iron (IV). A special developing paper called "imbibition paper", supplied by Eastman Kodak Co., is also used.

Apparatus — Referring to the sketch at right, *B* is the sample (which should have a ground surface or better); *C*, the imbibition paper; *A* and *D*, electrolytic contacts and connections; *E* is a piece of insulating rubber; *F* is the final support; *G* represents a convenient clamp support, although a large C-clamp would work just as well.



Clamp Assembly and Solutions Required for Macro-Etching Non-Ferrous Alloys to Show Iron, Lead and Nickel Segregates

Procedure — The imbibition paper is cut to the size required and soaked in the standard electrolyte for 5 to 10 min. Immediately before use, it is removed from the solution and excess liquid blotted off until the paper is just damp.

Test for Iron — The sensitized paper is placed in the assembly, as shown at *C*, with the emulsion side toward the sample, and the pile securely clamped. Ten volts are applied for 1 min. At the end of this time, the paper is removed and immersed in the tannic acid solution (IV). A purple precipitate indicates iron at the locations shown in the print. (EDITOR'S NOTE — See also the somewhat simpler test for iron, suggested later on by Mr. Savage.)

Test for Lead — Same assembly as for iron. Four volts for 15 sec., followed by a wash in 30% potassium cyanide solution (II), and development in 5% sodium sulphite solution (III). The lead shows up as dark brown areas on the print. (EDITOR'S NOTE — Mr. Evans, below, gives an alternative method for lead.)

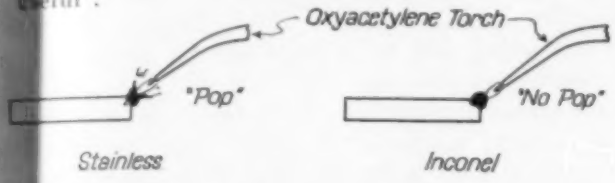
Test for Nickel — Same assembly as for iron. Apply 3 to 4 volts for 30 sec., followed by development in dimethylglyoxime solution (I). The nickel appears as pink spots on the print. (SIDNEY LENHOFF and ROBERT J. SHERMAN, Metallurgical Dept., General Motors Corp., Detroit Diesel Engine Div.)

Alternative Test for Iron — We have found a very valuable test for spots where we think some iron has segregated in our brass or bronze. It also shows iron in solution if there is any appreciable quantity, because the test is extremely sensitive: Put a drop of nitric acid solution (about 1:1) on the spot in question and after allowing a second or so to effect some solution, add a drop of a weak solution of potassium thiocyanate. If any iron is present, a deep blood red color will result. (PHILIP A. SAVAGE, Chief Chemist, Revere Copper and Brass, Inc., Michigan Division)

Alternative Test for Lead — Place a drop of 1:1 nitric acid on the piece to be tested, let spot develop until the copper color is very definite and take up on a small piece of filter paper that has been moistened with 1:6 sulphuric acid. Wash out the copper in the paper with 2% sulphuric acid and add a drop of a reagent containing 5 g. stannous chloride, 5 g. cadmium nitrate and 10 g. potassium iodide in 100 ml. distilled water. A yellow to orange color will appear if lead is present. (J. T. EVANS, JR., Chief Metallurgist, Haberfelde Steel Co.)

To Distinguish Stainless From Inconel

A MEMBER of the Royal Air Forces, who asks to remain anonymous (airforce regulations, you know), sketches the following and sends it in without further comment, except "This may be useful".



Polishing Soft Steel (Cartridge Cases)

CARTRIDGE CASE STEEL for 0.30-caliber ammunition is, we find, extremely susceptible to pitting when polishing for metallographic examination. The following routine takes less than 5 min. and gives an excellent surface free from defects and cold work.

From a No. 1 grit emery disk, the specimen is taken to a canvas lap where 240-mesh aluminous oxide is used in water suspension. From time to time a small quantity of soap solution is added to this lap to prevent surface smearing.

Secondly, the specimen is polished on a lap covered with an inverted "Selvyt" cloth, impregnated with alumina obtained by re-levigating bulk levigated alumina and using the residue. A very small quantity of soap is also used.

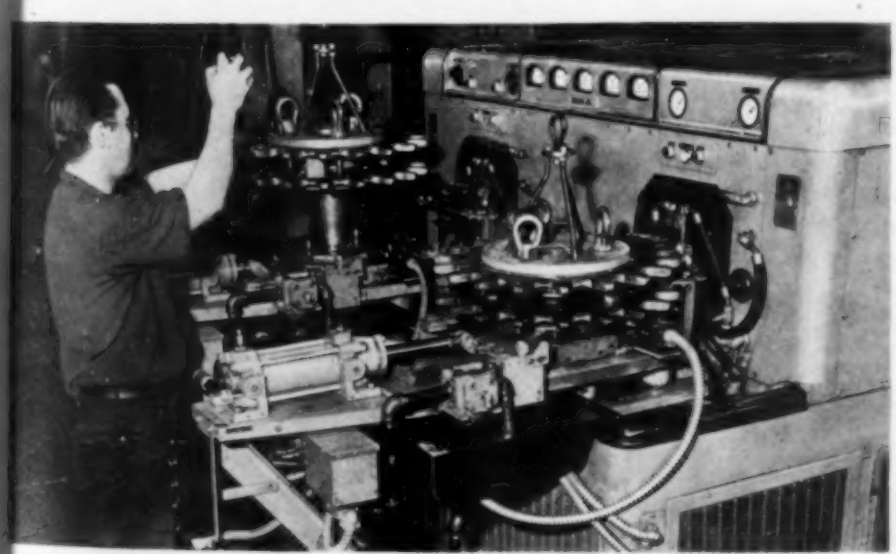
The final polishing is done on a billiard cloth lap using re-levigated alumina as abrasive.

NOTES: It was necessary to discard 600-grit aluminous oxide because of pits it caused.

We purchase levigated alumina dry, in 5 or 10-lb. lots. We mix this dry alumina with enough distilled water to give, on rapid stirring, a suspension of about the consistency of coffee cream. After making sure there is no powder stuck on the bottom of the container, we cease stirring and allow to settle for 10 min. Then the upper half of the mixture is decanted for the final polishing operation. The residue is poured and scraped out and used for the intermediate lap. (ROBERT F. NELSON, Assistant Metallurgist, Parker-Wolverine Co., Ordnance Division.)

Rapid Hardening of Sprockets

AN AUTOMATIC FIXTURE was recently designed for International Harvester Co. which hardens teeth on drive sprockets for half-trac combat vehicles at a saving of more than half the time formerly used. As shown in the attached view the completely machined sprockets of C1046 steel are bolted together in pairs in a handling jig. (Assembly and dis-assembly takes one operator 4½ min.) Placed on the handling fixture, a switch is thrown, subsequent actions are repeated automatically 18 times until all teeth are hardened, and then stopped. At the stroke of a hydraulic plunger, the fixture advances, pushing the teeth into the water-cooled inductor, which is of a simple open style design. Upon completion of the hardening cycle the fixture withdraws the sprockets, indexes, and advances again to the inductor. The hardening cycle consists of a 10-sec. heat, 4-sec. quench and 6-sec. index for a total of 20-sec. per station. The Tocco unit is a standard 50-kw., two-station machine for 9600-cycle current. Teeth are 2¼ in. deep, 1¼ in. wide at the base and ⅝ in. at the top. A hardness of C-51 to 58 is confined to the top and pitch line of the tooth, with depth not in excess of $\frac{5}{32}$ to $\frac{3}{16}$ in. The surfaces between the teeth at the root are not hardened. Sprockets are free of distortion and have complete reproducibility of case, tooth to tooth. (S. COVERT, Ohio Crankshaft Co., Cleveland)



Two-Station Induction Hardener Turns Out a Pair of Drive Sprockets Every Six Minutes, Hardening Teeth Two at a Time (One on Each Sprocket in Pancake Fixture). While machine works on one station, operator unloads and loads the other fixture and station

Recent experiments directed by the War Metallurgy Committee, at Rensselaer Polytechnic Institute and Lehigh University, have worked out the quantitative relationships between arc voltage, current and travel and the hardness and ductility of the heat affected zone in the base metal

Weldability of Steel

AMONG THE NUMEROUS REVIEWS of welding literature prepared by Messrs. Spraragen and Claussen for the Welding Research Committee and published as supplements to the *Journal* of the American Welding Society are included seven (7) very excellent summaries of various phases of the problem of "weldability".

The above statement, and nothing else, would indicate the extreme complexity of the subject. Likewise anyone whose acquaintance with the welding art dates back 30 years will realize that the connotation of the word "weldability" has gradually undergone a pronounced change. In the early days of the oxy-acetylene and arc welding industry about the only iron alloys which were regarded as readily weldable were wrought iron and soft steel; nowadays the attitude would largely be that *any* metal is weldable — all that is necessary is to discover the necessary technique and facilities. It goes without saying that this change of attitude by no means comprises an adequate understanding of the problem of weldability — rather it reminds me of what steel metallurgists faced in another situation, when they attempted to pin down the conception of "body" to definite quality factors possessed by high grade steel.

Not that various definitions of weldability have not been proposed from time to time. They have ranged from the ideal and impracticable proposal that a welded joint should be indistinguishable from the base metal in all respects, to a practical engineering definition requiring that no cracks develop in the joint after welding in a given routine, either before the joint is loaded or after it is loaded. Another idea, that weldability of a certain metal can be determined by welding a simple structure of it and inspecting it for defects, has the disadvantage that it must be associated with some standardized welding technique, else it has little practical meaning. Furthermore, the American Bureau of Shipping has recently had ample demonstration of the fact that perfectly sound metal welded by approved practices can develop disastrous cracks due to locked-up stresses — a matter which has but a tenuous connection with the "weldability" of the base metal, to say the least.

In making a tentative approach to such a complicated subject as the quantitative appraisal of weldability, it would consequently be best to circumscribe our efforts to the least number of considerations possible, provided only that these considerations are of primary importance. If we are to discuss the weldability of the base metal it would obviously be proper to eliminate close examination of the deposit at the very center of the weld. (I am assuming that what we are discussing is "fusion" welding, that filter metal of some sort is deposited, and the weld is not merely made by melting together abutting edges of sheet metal, or pressing faying surfaces together at hot spots.) For example, weld metal itself has been known to crack badly, with cracks branching off

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from the center of the joint toward the edges like the branches of a bare tree. These are akin to hot tears in steel castings and have more to do with the hot shortness of the metal *in the bead* than anything else. Hence we can neglect them in discussing weldability of *base* metal. It is not a cogent rebuttal that weld metal cracks are accentuated by the rigidity of the parts being welded, and that they are mitigated by preheating or quick stress relief. Without arguing the matter in detail, it will be assumed that weld-metal-cracks as well as "fish-eyes" are problems of welding technique and are not factors in any definition of weldability of base metal.

A logical extension of the above idea would discard consideration of troubles in the so-called fusion zone — that is, in the very edge of the puddle where there is a mixture between molten filler metal and molten base metal. Troubles might obviously be expected here if the composition of the filler metal were too different from that of the base metal; this very statement indicates again that the problems in the fusion zone are problems of welding technique rather than weldability of the base metal.

None of the above is to deny that a weld is a complex structure, nor to criticize the engineer who desires some over-all test that will integrate the effect of dozens of factors which have gone into the making of such a weld. There is something to be said, therefore, for the idea that "practical, commercial weldability" is possessed by metal if welded joints in it will have a tensile strength, bend ductility, and impact strength of 80% (say) of the corresponding properties of the unwelded steel. The principal trouble with such a definition is that testing engineers have found it very difficult to devise tests which are suitable for the comparison. To compare a joint with unjointed material by any test to destruction, the deformation and fracture should certainly reside in the joint — yet it is almost impossible to insure such conditions in as simple an undertaking as a tension test on a butt welded joint.

Cracks in Welds and Welded Structures

In reading the reviews prepared by Messrs. Spraragen and Claussen, one is struck with the frequency with which the thought is either implied or expressed that the principal trouble in welds is the development of cracks. Obviously a sound joint should not contain cracks; a weldable steel should be welded without cracking. For instance, we have definitions of weldability suggested by both Hodge and Gibson (well-known American welding experts) which may be stated as: "Weldability is the ability of any steel to go through a thermal cycle imposed by a given welding technique without the production of hard or brittle zones tending to produce cracks in welding or in service."

Cracking in service has loomed large enough in the literature to warrant a critical survey by Spraragen and Claussen. While many service failures have undoubtedly been studied in detail, only a few of these studies have been published — probably an indication that the commercial desire to cover up responsibility has triumphed over the engineering desire to confess one's sins so that others can avoid future trouble. However, when a busy bridge falls down, the matter can hardly be covered up except by wartime censorship; consequently the most valuable studies of cracks in structures in service describe failures of German and Belgian bridges. The troubles, principally if not exclusively, can be ascribed to dangerous multi-axial stresses.* Stress analysis after the event indicates such stresses *did* reside at the seat of the trouble, and examination of the fractures (showing no ductility at the break, yet in material ductile when tested) verifies this supposition. I will therefore lay down the dictum that cracks in structures in use are principally due to errors in design, careless welding, lack of proper stress relief, or improper work during field erection. If this is a proper statement of fact, it will follow that any amount of weldability in the base metal can hardly be expected to insure a structure that will be free of cracks after it gets into service; no metal is known which will act in a ductile manner under tri-axial stress.

This does not mean, however, that the definition of weldability should entirely disregard the possibility of cracks. On the contrary, it is fair to demand of a weldable steel that it be one that does not develop cracks any place in the base metal during the welding operation, and this brings us directly into the modern trend of studies on the entire problem.

There is a considerable literature on so-called "hard cracks" — very small, sometimes microscopic, cracks in the hardened zone of the base metal just adjacent to the fusion zone of the weld. "Hard cracks" are caused, according to some authorities, by the volume changes when austenite, existing at the time the welding heat is there, transforms into martensite, the hard

*Here the reader may look up and re-read an understandable note on Tri-Axial Stresses in *Metal Progress* for June, 1943, page 946.

product of quenching, this volume change taking place during a time when the adjacent metal is much more rigid. I rather think of "hard cracks" as resulting from a complex multi-axial stress system, which can crack even a plastic metal, and which actually is operating on material which is inherently brittle or in a range of temperature where it would be brittle anyway. It would appear that the simplest way to avoid such "hard cracks" would be to avoid the formation of martensite, and this of course is done in a practical way by welders by limiting the carbon content of the steel to, say, 0.20% carbon and keeping the alloys low. This, in modern metallurgical parlance, merely means that the steels transform rapidly at a high temperature from austenite directly into ferrite and fine pearlite — in other words, such weldable steels are not very hardenable. Another common method, of course, is to slow down the cooling rate of hardenable steels containing higher carbon or higher alloying content by preheating and using more welding heat. At any rate, there seems to be a definite hardness level, approximately the equivalent of Brinell 350, below which "hard cracks" may not be expected to occur.

Tests for Hard Areas

This brings us to the point where we find that recent experimentation in the United States favors the use of hardness traverses, using the Vickers hardness testing machine for its ability to measure spots close to each other without too much disturbance of the surrounding metal. Dozens of recent articles which have the word "weldability" in their titles have diagrams or tables showing the results of such hardness traverses along lines parallel to the top of the joint and at a depth approximately equal to the depth of the fusion zone at the last bead.

[EDITOR'S INTERPOLATION — "Weld Bead Hardness Test" is included in "Proposed Tentative Tests for Metal Arc Weldability of Steels" of the American Welding Society, as published in *The Welding Journal*, June 1943, page 433. Test plate is 3 by 6 in., ½ in. thick, normalized, and held at 65° F., 300° F., or —20° F., as the case may be. A bead 3 in. long is deposited along the center line with E6010 electrode, $\frac{3}{16}$ in. diameter, 25 volts d.c., reversed polarity, and 180 amperes. Speed of travel shall be carefully controlled at 5 in. per min. A ½-in. strip is then cut across the plate, narrow-wise, both cut surfaces polished with 000 emery and lapped, examined for cracks with a 25 power glass, then etched lightly with 1% nital to mark out the heat affected zone, and re-examined. Vickers hardness readings are then made on one face, spaced 0.03 in. apart along a line slightly below the fusion zone at the bottom of the bead. Maximum hardness readings to right and to left of center line is reported, as well as the hardness of the unaffected base metal, 3 in. from the center of the bead.]

We also find hardness limits in the 1941 Swiss standards for weldability, which are briefed as follows:

A steel to be weldable must melt without wildness and spatter, and be free from large inclusions and laminations.

A steel is classed as having "good" weldability if plates up to 1⅝ in. thick, welded at 40° F., will withstand a 30° bead-bend test (described below), have maximum hardness alongside the fusion zone of no more than 300 Brinell, and contain no martensite in cross-section.

Steel is of "adequate" weldability if plates up to ¾ in. thick can be so welded.

Plate has "bad" weldability if special technique and subsequent heat treatment are necessary to reduce the maximum hardness alongside the weld to 300 Brinell.

Steel is "not weldable" even if special precautions and heat treatment will not bring the hardness to 300 Brinell.

The bead-bend test noted above is a German development designed to search out the existence of very fine cracks in the base metal alongside the fusion zone and also to appraise the condition of the metal as to its ability to resist rapid propagation of cracks which might start at hard brittle spots. To prepare the specimen, a short bead is run down the center of the test plate (either grooved or not) and without further preparation the plate is bent in a fixture with the bead on the tension side and the direction of the bead perpendicular to the bending plunger. The angle required to open up the first transverse crack is measured, and this angle of bend (in German practice) must be at least 20° in order to conform to the standards for structural welds. Studies of the stress distribution along the edges of such a bead show that the resultant of the weld shrinkage stress and the bending stress during testing is an extremely high tensile stress localized near the tension surface; the bending operation thus tests a sub-surface region for residual stresses in the hardened area where the metal is least able to deform and equalize these concentrated stresses. Conditions appear to be much more severe in the vicinity of a single bead than in multi-pass unrestricted welds, and it is particu-

searching as to the effect of hard spots.* The welding conditions for laying down the bead are not critical; in fact, the things which make a marked change in the bead-bend test are also those which have to do with the "weldability" of the base metal. That is to say, normalized plate will resist the spread of cracks once started; a stress relieved bead will increase the angle where the first crack appears; laying a bead on a preheated plate will do the same.

However, the maximum hardness is not clearly related to the angle of cracking in the bead-bend and that is responsible for developing the idea that weldability is best measured by appraising two important characteristics: *(a)* The maximum hardness developed just under the fusion zone, and *(b)* the ability of the plate to bend, preferably after being notched with a standardized groove. These two ideas are the basis of two fine pieces of recent American research. Each is founded on the assumption that *all* engineering steels, carbon or alloy, are weldable once the arc is properly controlled as to voltage, amperage and speed of travel. Weldability is not measured; it is assumed; the problem is to find the correct current.

As remarked above, recent studies of weldability use the Vickers hardness machine for exploring the hardness of the bead fusion zone and the heat affected region in the base metal. Confining, for the reasons outlined above, our attention to the maximum hardness in the base metal, it is obvious to metallurgists but had to be proven to some welding engineers that the maximum hardness under standardized welding routine varies with the composition of the steel and its grain size — that is to say, with the hardenability of the steel as measured either by Grossmann's method or by the Jominy test.†

Likewise, the maximum hardness in the base metal has been experimentally shown to vary with the welding speed, the current in amperes, the arc length, the electrode size, and the type of coating — all factors involved in the amount and rate of heat input. Finally, the maximum hardness varies with the thickness of the plate, its temperature, and with auxiliary chilling methods — that is, with the cooling rate after welding.

This sums up to what might be readily predicted from metallurgical considerations, namely, that the maximum hardness depends upon the hardenability of the steel and the heating and cooling cycle experienced by the region under study. Perhaps it is an over-simplification, but such American experts as Hodge, Gibson, Bibber and Warner have been recorded as saying in effect that "weldability is inverse to hardenability", and a metallurgist might add that hardenability can be expressed quantitatively, so weldability also should be definitely measurable.

Jackson and Rominski have gone so far as to propose four grades of steel based on "the average hardness of the heat affected zone":

Classification of Weldability (Jackson and Rominski)

Grade	Average Brinell Hardness	Preheat	Stress Relief
I	Under 200	Unnecessary	Unnecessary
II	200 to 250	Slight, for thick plates	Thick (or thin) parts
III	250 to 325	300° F.	All sections
IV	Over 325	400° F.	Without cooling from preheat

Much in the same train of reasoning, Wendell F. Hess, associate professor of metallurgical engineering at Rensselaer Polytechnic Institute, and his associates set out to find the actual relationship between the heat input of normal welding operations corresponding to definite cooling rates and hence definite hardnesses and microstructures in the base metal $\frac{1}{32}$ in. from the fusion zone. The research was under direction of the War Metallurgy Committee and financed by the Chicago Bridge and Iron Co., the Welding Research Committee of the Engineering Foundation, and the National Defense Research Council. The experiments were performed on various thicknesses of plain low carbon ship steel, but sufficient work was also done on low alloy and other steels to indicate that cooling rates were substantially independent of steel composition — a finding that was predictable since it is known that a moderate amount of alloy does not change noticeably the thermal coefficients of steel. The research, as published in the Research Supplement of *The Welding Journal* for September

*Editor's Footnote — Welding dangers are even more intensified in the two fillet welds in a T joint. For that reason the A.W.S. proposed tentative test for weldability noted in the interpolation above uses such a joint "to indicate the inherent weldability of a steel" and standardizes conditions for welding and testing. Three 1¼-in. bend specimens are cut across the joint (originally 24 in. long in ½-in. plate), bent in a standard fixture so that the top of the tee is forced back, stretching the fillet welds. Maximum loads, bending angle for first crack, and nature of crack are observed (as well as a hardness survey), but no plan of quantitative valuation is suggested.

†See *Metal Progress;* July 1942, page 80, and December 1941, page 911.

Energy Input in 10^3 Joules per Inch Required to Produce Various Cooling Rates at 800° F.

Top Pass Butt Welds; Plate Thickness 1 In.; Electrode ¼ In.

Cooling Rates °F/Sec.	Plate Temperature, °F.								
	37	72	100	150	200	250	300	350	400
6							100.4	91.8	83.0
8						96.8	88.0	80.0	72.5
10		*115.0*	109.5	99.8	90.6	82.5	75.4	68.7	62.0
12		*105.5*	100.0	90.4	81.6	73.8	67.3	59.4	52.5
14		97.0	91.8	83.3	75.3	67.7	60.0	52.3	45.0
16	96.0	89.2	85.2	77.8	70.0	62.3	54.8	47.3	39.8
18	90.0	85.0	80.4	73.0	65.5	58.0	50.3	42.9	35.3
20	83.0	77.5	73.8	66.8	59.5	52.5	45.6	38.6	31.7
22	77.5	72.4	69.0	62.2	55.5	48.9	42.1	35.7	28.9
24	73.0	68.0	64.6	58.1	51.8	45.3	39.1	32.8	26.5
26	69.5	64.0	61.0	55.0	48.8	42.7	36.7	30.3	24.5
28	66.3	61.6	58.3	52.2	46.4	40.2	34.5	28.7	22.8
30	63.2	59.0	55.8	50.0	44.1	38.5	32.8	27.1	21.5
35	56.8	52.5	49.8	43.8	38.0	32.9	27.9	22.9	18.0
40	51.3	47.1	44.1	38.9	33.3	28.0			
45	46.5	42.6	40.1	35.1	29.9	25.0			
50	42.3	38.7	36.0	31.6	27.0				
60	35.2	32.3	30.0	26.0					
70	30.0	27.2	25.1						

1943, attained its general objective, which was to evaluate the weldability of steels for the arc welding fabrication of tanks, gun mounts and other war *matériel* — evaluating "weldability" in the sense that the results enable the engineer to select optimum welding conditions as to speed of travel of the arc, the amperage and the voltage for a given steel. The fundamental assumption is, of course, that *any* constructional steel is weldable if the correct technique is known.

The experimental work consisted of recording cooling curves of points within ship plate located $\frac{1}{32}$ in. from the edge of the fusion zone of a bead run down the plate. It will be remembered that the last bead of a multi-pass weld, or a single bead on a plate, will locate the region of fastest cooling (and, inferentially, of greatest hardening). Cooling curves of this sort were made for ship plates varying from ¼ to 1½ in. thick, using an automatic welding head with covered electrodes ⅛ or $\frac{3}{16}$ in. diameter, varying the energy between the practical maximum and minimum of currents and voltages. Plates were welded at 37, 72, 210, and 400° F.

From these curves the cooling rates in degrees Fahrenheit per second could be measured at any point in the cooling cycle, for any of the conditions tested. The cooling rates were so measured by 100° steps from 700 to 1300° F., and the results correlated to a mathematical equation representing heat transfer from a hot spot to a cold region. The various coefficients of this rather complicated exponential equation were determined from the mass of experimental evidence by the use of graphical and statistical methods. Quantitative expressions thus obtained fitted the experimental cooling rates very closely, and enabled the data to be extended considerably and interpolations derived so the tables eventually calculated and published in the report give almost any desired information. These tables show the energy input required to produce cooling rates of definite amounts at temperatures between 700 and 1300° F. by 100° steps, for any plate temperature from 37° to 400° F. by 50° steps, and for any plate thickness from ¼ to 1½ in. by ⅛-in. steps.*

Two other items are required in the use of this mass of data — *(a)* a Jominy end-quench bar of the steel to be welded, and *(b)* a knowledge of the transformation characteristics (or the S-curve) sufficient to indicate the temperature range wherein the given steel transforms the fastest. The cooling rates to avoid martensite, or to give a definite microstructure shown at any point on the Jominy bar, are known because the cooling curves for various points along a Jominy bar have long since been determined.

As an example of how these tables may be used, let us pose the following problem: What current and voltage setting, as well as arc travel, would be necessary to weld a 1-in. plate of NE8620 at room temperature in order that the heat affected zone in the base metal may be completely free of acicular or martensitic constituent — that is, have a structure of ferrite and fine pearlite? It is known in general terms that the steepest part of the curve which plots the hardness along the length of the end-quench bar corresponds to a microstructure of half martensite and half soft constituent; similarly, less than 10% of martensitic or acicular constituent is found in the microstructure at the point where the Jominy hardness curve flattens out from the steep portion into deeper regions of low hardness. An actual Jominy curve made by Professor Hess for a heat of 8620 (first coarsened by heating to 2100° F.) shows that this transition to low hardness (practically complete absence of hard constituent) occurred at $\frac{15}{32}$ in. from the end, where the hardness is approximately 275 Brinell. Knowledge of the S-curve of NE8620 also indicates that the "nose of the S-curve" is located between 900 and 700° F., and reference to other

*It is hoped that *Metal Progress* will be able, in some future issue, to present these tables in the form of alignment charts for ready computation, if it is found possible to rearrange and record the tabular data in this manner.

curves giving the cooling rate of the Jominy bar $\frac{15}{32}$ in. from the end shows that this point requires 17 sec. to go from 900 to 700° F. *Average* cooling rate, therefore, through the danger zone is 200 ÷ 17 or 11.8° F. per sec.

Now entering the table shown on page 302 (worked out by Hess and co-workers for ½-in. plate at 70° F., welded with ¼-in. electrode), giving cooling rates at 800° F., the rate of 11.8° F. per sec. is found to correspond to an energy input of 106,500 joules per in. This will give the required heat put in by the welding current, no more, no less, so the base metal just under the fusion zone will cool at the same rate through the fast transformation temperature range that the Jominy test bar cools at the spot where its hardness is about 275 Brinell. Assuming an arc voltage of 32½, and travel speed of 7.1 in. per min., the amperage is readily figured from the simple equation

$$\frac{\text{(joules per in.)} \times \text{(travel speed, in. per min.)}}{60\ \text{(arc voltage)}}$$

Making the necessary substitutions, we get 386 amperes as the required current.

When the welding machine was set to these figures and the weld actually made in a butt joint between 1-in. plates of NE8620, a hardness survey showed that the actual maximum hardness was 283 on one joint, and 279 on a second joint — practically a perfect check.

Controlling Ductility *and* Hardness

The studies made by Prof. Gilbert E. Doan and his associates at Lehigh University were also supported by the National Defense Research Committee and directed by the War Metallurgy Committee. They differ from the Rensselaer studies principally in introducing the very important factor of ductility. It is assumed that desirable welding will preserve the ductility of the base metal, and it is easily possible that certain base metals retain adequate ductility at a much higher level of hardness than others. So much the better; we then will have strong, ductile metal, a very desirable constructional material.

Hardness for various cooling rates can readily be measured by the Jominy test. *Ductility* corresponding to definite hardness for definite steels has not ordinarily been determined, but Kinzel's suggestion was adopted by Doan to measure it thus: A number of long test bars are heated to 2100° F. to coarsen the microstructure, cooled slowly to 1500° F., and then cooled each one at a different rate, as in iced brine, cold water, warm water, oil, air blast, still air, and lime. This will, of course, give a number of bars of various hardnesses and the ductility of each is measured by cutting a standard Izod V-notch across the face, and bending it slowly to failure with the notch in the tension side, measuring the angle where the first crack appears. These angles are then placed on the graph showing the hardness of the Jominy bar at the respective positions. Data for a coarsened heat of NE8620 are shown above.

Tests on NE8620

Jominy Position*	Vickers Hardness	Ductility†
2	414	10°
2½	409	10
3	403	11
3½	395	11
4	385	12
4½	373	13
5	360	14
6	330	16
7	292	20
8	268	23
9	260	24
10	253	25
12	243	27
14	240	28
16	235	29
18	233	29
20	230	29
22	228	30
24	223	31

*Distance from end in sixteenths of an inch.

†Angle of bend of notched bar.

The engineering evaluation of this ductility test will be difficult because such tests have not been standardized nor widely performed. It will require considerable experience and engineering judgment, but the sponsors of the test believe that a bend angle of 20° is satisfactory ductility for constructional materials and welds possessing that much ductility could be used without stress relief; any material having from 10 to 20° notch bend ductility would require stress relieving.

The principal table of data prepared by Professor Doan and his associates at Lehigh is similar to the ones prepared by Professor Hess at Rensselaer in that it gives the number of kilowatts required for the last pass in butt welds in ½-in. plate of definite preheating temperature, and at given welding speeds, to produce a cooling rate equivalent to various points down the Jominy hardenability test bar. (A portion of this master table is reproduced later.) It is assumed that the base metal does not evolve gas on melting, is not laminated, is not hot short, and has satisfactory notch-bar strength in the as-used condition; in these respects the requirements are similar to the Swiss specification mentioned.

The master table is based on the final bead or last pass on a ½-in. butt joint, and an additional factor called "joint geometry" is necessary for thicker plates or other types of joint. These

Kilowatts for Last Pass Butt Welds in ½-In. Plate

Jominy Position	Plate Temperature	Welding Speed, In. per Min.							
		2	3	4	6	8	10	12	18
6/16	32° F.	1.6	2.4	3.2	4.8	6.4	8.0	9.6	14.4
	75	1.5	2.2	3.0	4.5	6.0	7.5	9.0	13.5
	200	1.3	2.0	2.6	3.9	5.2	6.5	7.8	11.7
	300	1.1	1.7	2.2	3.3	4.4	5.5	6.6	10.0
	400	1.0	1.4	1.9	2.7	3.8	4.6	5.4	8.1
7/16	32° F.	1.8	2.7	3.6	5.4	7.2	9.0	10.8	16.2
	75	1.7	2.6	3.4	5.1	6.8	8.5	10.2	15.3
	200	1.5	2.3	3.0	4.5	6.0	7.5	9.0	13.5
	300	1.4	2.1	2.7	4.1	5.4	7.0	8.2	12.3
	400	1.2	1.8	2.4	3.6	4.8	6.0	7.2	10.8
8/16	32° F.	2.0	3.0	4.0	6.0	8.0	10.0	12.0	18.0
	75	1.9	2.9	3.8	5.7	7.6	9.5	11.4	17.0
	200	1.8	2.6	3.5	5.3	7.0	8.8	10.5	15.8
	300	1.6	2.4	3.2	4.8	6.4	8.0	9.6	14.4
	400	1.5	2.3	3.0	4.5	6.0	7.5	9.0	13.5

geometry factors were derived after a considerable amount of experimentation, and verify the principle that the higher the rate of heat input, the slower the cooling rate at the critical spot. The geometry factor is directly proportional to plate thickness — for instance, the bead on a 1-in. plate (or the last pass on a butt weld) requires twice the heat that is required in the ½-in. plate to produce the same cooling rate under the weld as in the ½-in. butt described in the table; that is to say, a 1-in. butt has a geometry factor of 2. Similarly, the first pass in a V or U-weld needs 5% less heat than the bead on the corresponding plate; the first pass fillet or lap weld requires 50% more; the first pass in a V-weld with a backing strip needs 10% more than the basic amount shown in the master table.

Let us see how Lehigh data would handle the problem posed above, namely, a butt weld in 1-in. plate of NE8620 welded at 75° F.

Assuming this to be a new steel or a questionable heat of old steel, a Jominy bar is tested, the metal first having been coarsened by heating to 2100° F., and other coarsened bars heat treated, notched, and bent as above indicated. The hardness vs. ductility relationships found in this way are given in the three columns above, and it is evident that a good combination of hardness (255) and ductility (22°) is had $\frac{15}{32}$ from the end of the Jominy bar.

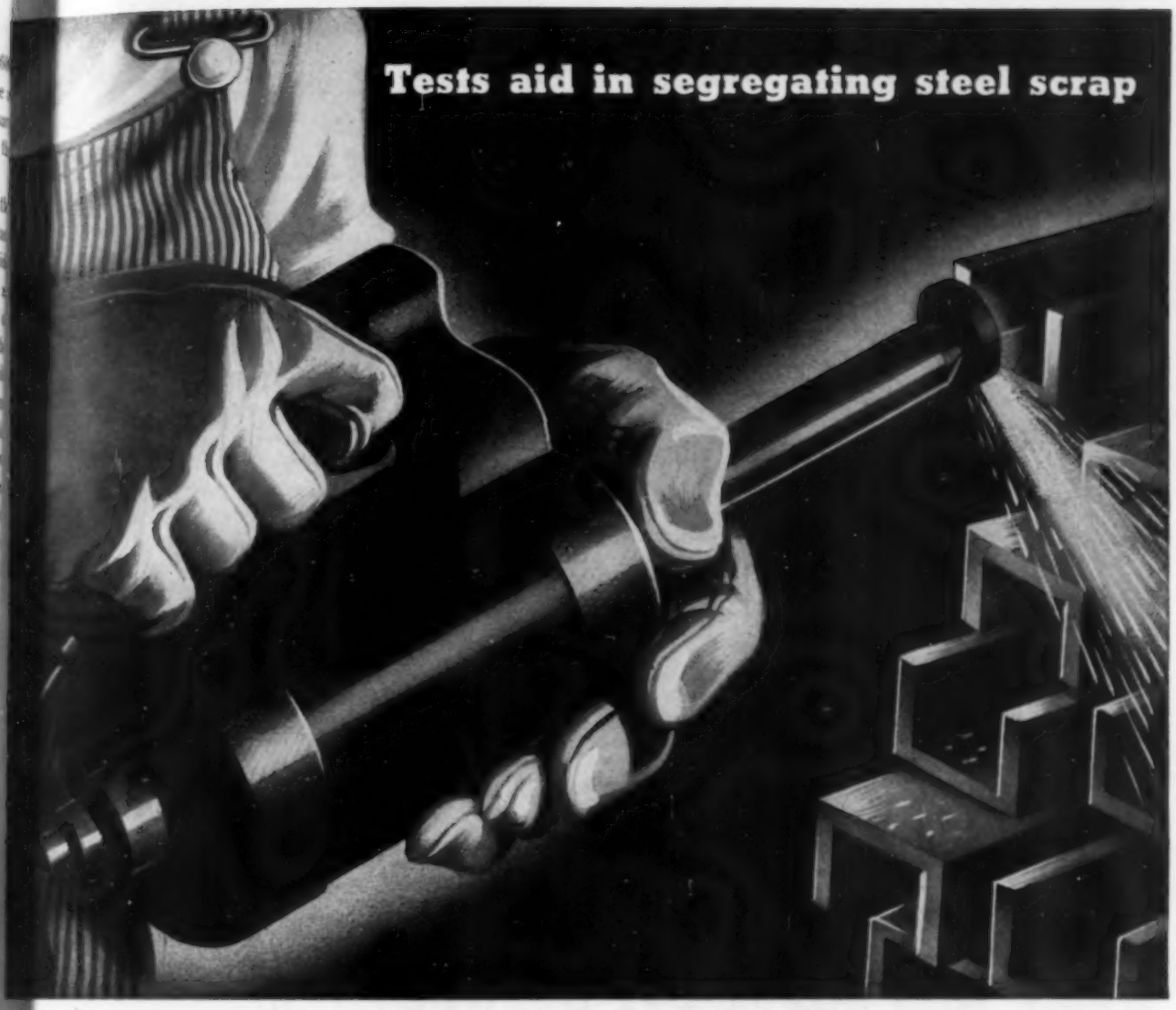
We now enter the master table to find the kilowatts necessary to produce the same cooling speed as exists $\frac{15}{32}$ from the end of the Jominy bar. (A faster rate would give harder and less ductile metal.) Assuming welding speed of 7 in. per min., the tabular value for plate at 75° F., $\frac{15}{32}$ from the end, is interpolated as 6300 watts. This would be correct for a butt weld in ½-in. plate, but since we are welding a 1-in. plate, we have a geometry factor of 2, which means that the required watts is twice 6300 or 12,6 Assuming a voltage of 32½, the same in the original problem, the necessa amperage is 385, which checks t Lehigh solution.

It should be emphasized that t methods developed both at Rensselaer and at Lehigh are intended as a gui to the "weldability of the base metal influenced by its reaction to the heat welding in the region adjacent to th weld metal, and definitely not as a gui to welding in its totality". Conditio may easily be hypothecated which wo demand such high currents and slo speed as to introduce even more seri problems with respect to the deposit metal. Both methods are based on cooling cycl to prevent high hardness; at Rensselaer the co ing curves actually were measured; at Lehig University the cooling curve for a definite hard ness under a weld in a given steel is assume to be the same as the cooling curve of the poi in the Jominy specimen having correspondin hardness (whose cooling curve has been worke out by others for other purposes). The Ren selaer method enables one to predict fairl accurately the cooling rate of the dangerou region in the base metal at any given temperatur level, and a fairly high degree of metallurgica intelligence is needed to predict this region fro the S-curve of isothermal reaction and relate thi with the resulting microstructure and hardness.* It however might be useful in cases where it i suspected that the cooling rate through the cri ical temperature zone is different in a weldmen than it would be in a Jominy test piece at th spot giving equivalent hardness, and likely wi be favored in studies of the high alloy steel where a given hardness is possessed by variou mixtures of fine pearlite, bainite, martensite an retained austenite.

The principal advantage of the Lehig method is that it correlates, apparently for th first time, the very important factor of ductility which is actually measured and not merel inferred as being inverse to the hardness of steel

Naturally, as good agreement between pre dictions and practice *(Continued on page 316)*

*Editor's Note — Since the reactions after weld ing occur on a continuously cooling cycle, rather than at a steady elevated temperature, the "S-curve" as determined by Liedholm in *Metal Progress* last month (page 94) will be more immediately applicable than the "S-curves" of isothermal reaction, popularized by the work of Davenport and his associates in U. S. Steel Corp. Research Laboratory.



Information supplied by an Industrial Publication

The loss of recoverable alloys in steel scrap has been a major problem confronting the various conservation agencies. Proper segregation of scrap is one effective answer.

Segregation of scrap at the source is comparatively simple. The difficulty comes in preventing mix-ups in subsequent handlings. They can be prevented or remedied by applying two simple tests—spark and spot.

The presence of molybdenum, or nickel, or both, is readily detected by spark testing. Molybdenum causes an easily recognized secondary burst at the end of the spark stream resembling a spearpoint. Nickel produces a spot of intensely white light in the stream near the grinding wheel.

Both elements have a tendency, in the higher contents, to suppress the supplemental bursts characteristic of carbon steels.

Several spot tests for molybdenum have been developed. The simpler ones depend on the red color produced by either potassium ethyl xanthogenate or sodium thiocyanate added to a molybdate obtained from the etched surface of the steel. The dimethyl glyoxime test for nickel also depends on a red coloration. Many of these tests are approximately quantitative.

CLIMAX FURNISHES AUTHORITATIVE ENGINEERING DATA ON MOLYBDENUM APPLICATIONS.

ARMY E NAVY

MOLYBDIC OXIDE, BRIQUETTED OR CANNED • FERROMOLYBDENUM • "CALCIUM MOLYBDATE"

Climax Molybdenum Company

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MOLY

Personals

HORACE B. VAN VALKENBURGH has become associated with W. A. McGrew in the practice of patent law in Denver.

W. B. LEYDA, formerly with A. O. Smith Corp., Milwaukee, is now chief metallurgist for Tubular Alloy Steel Corp., Gary, Ind.

Promoted by Carnegie-Illinois Steel Corp.: A. N. SWANSON, to chief process metallurgist in the Chicago Metallurgical Division; succeeded as chief metallurgist at the Gary Works by C. J. HUNTER, formerly coordinator of armor plate products for the Pittsburgh general office; JOHN E. ANGLE, from division superintendent to assistant general superintendent of the Gary Sheet and Tin Mill.

THOMAS J. DORAN, patent lawyer, has been admitted to partnership in the firm of Hyde Meyer, Cleveland.

E. B. FARRIS, formerly nected with Edgar T. Ward's Co., has been appointed to re sent the Steel Division of the perweld Steel Co. in Clevelan

MARVIN G. SEDAM, form chief metallurgist in charg welding rod research and dev ment for the Harnischfeger C Milwaukee, has been appointe rector of research for the Rods Co., York, Pa.

E. R. PARKER has resigne a research metallurgist for Ge Electric Co. in Schenectady an now at the University of Calif Berkeley, Calif., working on research problems.

WENDELL A. MANSFIELD merly with Fafnir Bearing Co., Britain, Conn., is now affili with the Newman Mfg. Co., Kansas City, Mo., as a tool engi

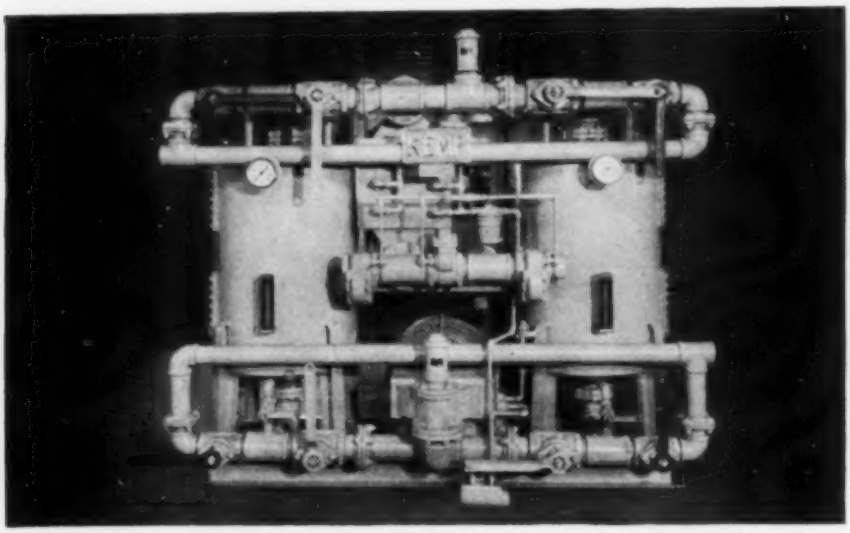
RALPH L. WILSON, for chief of the Constructional S Section of the Metallurgical Conservation Branch, Steel I sion, War Production Board, returned to the Timken Roller B ing Co., Canton, Ohio, as c metallurgical engineer. WALTE HILDORF, former chief metall gical engineer, has been na director of metallurgy.

H. M. SCHLEICHER, form with Scovill Mfg. Co., Carte N. J., is now employed as metall gist, The American Metal Co., L New York City.

E. W. KEMPTON has been pointed supervisor of the metall gical section of the Remingt Rand, Inc. Propeller Division T ing Laboratory at Johnson C N. Y.

Resigned from C. M. Kemp Co., Baltimore, Md.: E. B. DUNN, vice-president and general ma ager, and R. S. VAN NOTE, sa manager.

EDWARD C. HOENICKE, assi ant to the general manager, found division, Eaton Mfg. Co., Detro has been appointed consultant the Gray Iron Castings Section cently organized in the Forgi and Castings Branch of the W Production Board.



Whatever your drying problem . .

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K. S. G. silica gel adsorptive dryers are speeding forced draft production in every war industry* that faces problems in drying gases, liquids or solids.

Kemp Silica Gel Dryers are available on prompt notice in a wide variety of standard types and sizes, while specially engineered units to meet special requirements are furnished as quickly as war conditions permit. To summarize, standard units are made in capacities from ten to 100,000 c. f. m., from atmospheric pressure to very high pressures. Activation is by gas, electricity or steam as desired, with single tower units for intermittent operation or twinned towers for continuous production.

To paraphrase a famous (and living) U. S. General, standard units may be had RIGHT NOW, special designs will take a little longer. C. M. Kemp Mfg. Co., 405 East Oliver Street, Baltimore-2, Maryland.

ARMY E NAVY

***Except the dehydration of foods, which is a different problem altogether.**

KEMP of BALTIMORE

A NEW RESOURCE HAS BEEN DEVELOPED

THE WEALTH of America has been wrought from her natural resources of fertile lands, wide forests and rich mineral deposits by the brains and muscles of her people.

But another resource is now available. A new source of wealth and well-being has been developing gradually and almost unnoticed which is tremendously important today and of still greater importance for tomorrow.

This new resource is the research laboratory.

Today, in hundreds of industrial and college laboratories, trained minds are expanding the world's knowledge, and applying the results of research to industry and to war.

In the Bell System, research has always been a fundamental activity. The telephone was invented in a research laboratory. And for years Bell Telephone Laboratories has been the largest industrial laboratory in the world.

Underlying modern research is the realization of vast latent values in nature. Although the lone genius does from time to time bring to light some part of these hidden values, only organized scientific research can assure the thorough exploration that will render the full measure of use for human welfare.

Research means imagining and experimenting. It means the searching out and bringing together of facts. It means clear statements of problems, precise measurements and keen analysis. It means tenacious following along unexpected paths.

These are the procedures of research. Its consummation is the grasping by subtle minds of relationships in nature no one has previously known. And on the basis of the broader knowledge so established are built new materials, new methods and new structures to serve the people of America.

The Bell Telephone Laboratories has now concentrated its efforts on communication systems and equipment for the armed forces. When the war is over its researches in communication will again be applied to an ever-improving telephone service in America.

BELL TELEPHONE SYSTEM

Personals

ALBERT KATZ is now in the research department of Aga Metal Tube Co., Springfield, Ohio.

A. H. SMITH has left Republic Steel Corp., to become chief metallurgist for Cadillac Motor Car Division of General Motors Corp., Detroit.

LEIGHTON M. LONG has resigned as chief metallurgist and foundry superintendent of the Bunting Brass and Bronze Co., Toledo, Ohio, to become an assistant research supervisor at Battelle Memorial Institute, Columbus, Ohio.

DANIEL W. TALBOTT, formerly plant superintendent of the recently shut down South Plant of Ohio Steel Foundry at Lima, Ohio, is now plant superintendent for C Plant of Symington Gould Corp., Rochester, N. Y.

H. J. HUESTER, formerly with Reynolds Metals Co. as technical advisor and director of quality and inspection for the aluminum plants at Louisville, Ky., and Lister Hill, Ala., is now a Bureau of Aeronautics general representative at Wright Field, Dayton, Ohio, with the rating of lieutenant commander.

JOHN D. MACCARTHY has left Remington Arms Co., Bridgeport, Conn., to become general superintendent of tool production at General Motors Corp. Eastern Aircraft Division, Linden, N. J.

ROBERT B. SMOCK has been assigned by the Glenn L. Martin Co. to source inspection at the Aluminum Co. of America, New Kensington, Pa.

B. A. ROGERS has been transferred to Albany, Ore., to be supervising engineer of the Northwest Electrodevelopment Laboratory being established by the U. S. Bureau of Mines.

Transferred by Vanadium-Alloys Steel Co.: JOHN N. STURMER, from Rochester, N. Y., to St. Louis, Mo., as district manager.

V. C. MEKEEL, superintendent of foundries of Ampco Metal, Inc., Milwaukee, has resigned his position to accept the management of product engineering and sales development for Syncro Machine Co., Rahway, N. J.

E. R. STARKWEATHER, formerly metallurgist for Lufkin Foundry and Machine Co., is now in the research laboratory of the Carborundum Co., Niagara Falls, N. Y.

J. WILLIAM PEAK has recently established the Peak Engineering Co. in Alexandria, Va., and is serving as president. He is also employed in the U. S. Naval Torpedo Station with the rating of temperer.

WILLIAM R. JOHNSON, formerly with Halcomb Steel Division of Crucible Steel Co. of America, Syracuse, N. Y., is now metallurgist with Metallurgical Laboratories, Inc., Philadelphia.

W. C. HAMILTON is now research consultant for American Steel Foundries, Chicago.

DURALOY

HIGH ALLOY CASTINGS

FOR MORE than twenty years Duraloy Metallurgists and Foundrymen have been producing castings with the correct proportion of alloying elements. Because each High Alloy Casting requirement presents its own problems and requires special consideration, the importance of experience is self-evident.

Let Duraloy take care of your next chrome-iron or chrome-nickel castings. They will be alloyed by Metallurgists who understand process plant requirements and poured by Foundrymen who know how to handle high alloy castings . . . an art in itself.

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Kodak Industrial X-ray Film, Type M Primarily for million-volt work. This newest Kodak Film has extra fine grain, high contrast, and is particularly effective for most million-volt work . . . for aluminum and magnesium alloys at average voltages . . . and, for general use, where highest definition is desired and high film speed is not required.

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Kodak Industrial X-ray Film, Type F Primarily for the radiography, with calcium tungstate screens, of heavy steel parts. Has the highest available speed and contrast with calcium tungstate intensifying screens. Also used for gamma radiography —direct and with lead-foil screens.

Kodak Industrial X-ray Film, Type K Primarily for the radiography, direct or with lead-foil screens, of lighter steel parts. Has the highest available speed in direct x-ray exposure . . . when used with lead-foil screens at higher voltages . . . and, for heavier parts, with gamma rays.

★

Kodak's research in industrial radiography began in 1927, and the experience and knowledge gained in this 17 years may be of value to you in your particular application.

EASTMAN KODAK COMPANY

X-ray Division **Rochester 4, N. Y.**

Personals

A. WESSMAN, formerly radiologist with Chicago Bridge & Iron Co., is now in the inspection department of C. F. Braun Co., Alhambra, Calif.

ATTILIO I. SEGRE is now research chemist for Fratelli Branca Co., Inc., New York City.

WILLIAM T. SNYDER, B.S. in Metallurgical Engineering, University of Notre Dame, Oct. 1943, is now assistant metallurgist, Douglas Aircraft Co., Inc., Chicago.

FRANCIS S. JACOBSON, formerly assistant chief metallurgist, Great Lakes Steel Corp., Ecorse, Mich., is now chief metallurgist for the Kaiser Steel Co., Fontana, Calif.

Transferred: MAJ. F. H. STARR, from the Los Angeles Regional Office to the San Francisco Ordnance District Office, to become chief of the production equipment and the fuels and utilities section; also local redistribution and salvage officer.

G. L. CRAIG, formerly New York representative for Calumet & Hecla Cons. Copper Co., is now director of research covering both the Calumet and Wolverine Divisions.

W. E. BOYLE has left Consolidated Aircraft Corp., San Diego, Calif., to take a position as instrument engineer for Shell Oil Co.'s new catalyst cracking plant at Wood River, Ill.

WILLIAM T. DELONG, field service engineer for Buick Motor Division of General Motors Corp., is now attached as a civilian to a mechanized unit in Texas.

J. ROBERT HENRY, who recently helped organize the Warren City Tank and Boiler Co. as the Warren Fabricating Division of the Taylor-Winfield Corp., has been appointed welding engineer for the Cleveland Diesel Engine Division of General Motors Corp. at Cleveland.

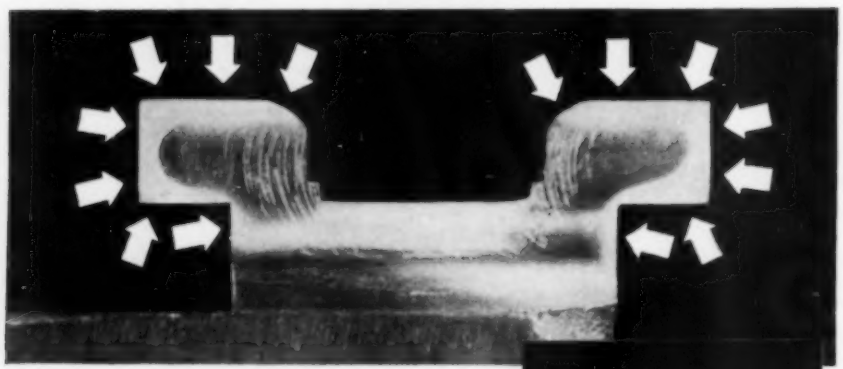
Promoted by Lukens Steel Co., Coatesville, Pa.: WILLIAM G. THEISINGER, from director of welding research to assistant to vice-president.

MAJOR CARL K. STEWART, formerly development metallurgist for the Irvin Works, Carnegie-Illinois Steel Corp., is now chief of technical control in an 8th Air Force Base Depot somewhere in Britain.

JAMES TERRY has been appointed district manager of the Cincinnati sales office and warehouse of the Columbia Tool Steel Co., succeeding W. G. SONDERMAN, recently deceased.

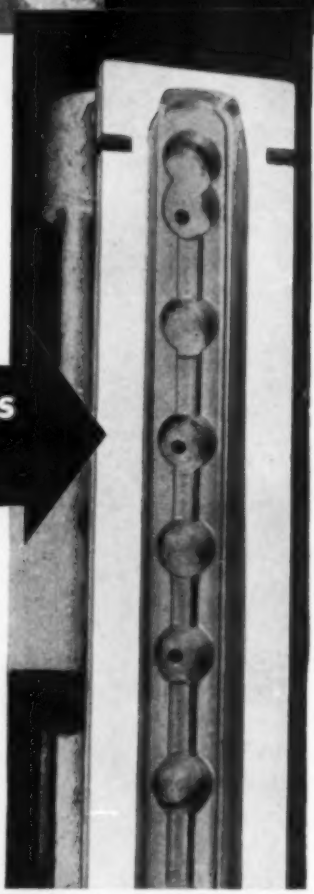
ROY G. ROSHONG, formerly with Harvey S. Pardee & Associates, is now technical advisor, Reynolds Metals Co., Plant 7, Louisville, Ky.

A. L. GRINNELL, district manager for the Rustless Iron and Steel Corp. in Detroit, has been appointed special representative on special assignments in Detroit; H. S. RUDESILL, sales representative in the Detroit office, has been appointed district manager.



Bearing surfaces of wear-resisting Ampco Metal *cost less..*

-with welded overlays of Ampco-Trode



Welding — the fabricating method which has made such tremendous strides in war production — offers you an economical means of building up surfaces that resist wear, shock and corrosion.

With Ampco-Trode, you can overlay less costly base metals with the same high-quality aluminum bronze which has found such wide acceptance in the form of castings and wrought products as Ampco Metal. Any grade of Ampco-Trode — selected for your required physical properties — can be welded to almost all metals and their alloys.

From giant marine propellers to the smaller machine parts or valve seats, you can apply aluminum bronze where needed. (Illustrated: gun slide overlaid with Ampco-Trode on bearing surfaces.) Write, for Ampco-Trode catalog.

W-1A

AMPCO Metal

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The Metal without an Equal

Sand Castings . . Centrifugal Castings . . Extruded and other Wrought Products . . Precision-machined Parts . . Ampco-Trode (coated welding electrode) . . Ampco Non-Sparking Safety Tools

TEAR OUT AND MAIL COUPON TODAY!

Ampco Metal, Inc., Dept. MP2, Milwaukee 4, Wis.
Please send Ampco-Trode Bulletin with information on wear-resisting welded overlays of Ampco Metal.

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. . . YOUR 4TH WAR LOAN QUOTA

WHETHER your plant meets its quota, or fails, lies largely in *your* hands. Your leadership can put it over—but if you haven't already got a smooth running, hard hitting War Loan Organization at work in your plant, there's not a minute to lose.

Take over the active direction of this drive to meet —*and break*—your plant's quota. And see to it that every one of your associates, from plant superintendent to foreman, goes all-out for Victory!

To meet your plant's quota means that you'll have to hold your present Pay-Roll Deduction Plan payments at their all-time high—plus such additional amounts as your local War Finance Committee has assigned to you. In most cases this will mean the sale of *at least* one $100 bond per worker. It means having a fast-cracking sales organization, geared to reach personally and effectively every individual in your plant. And it means hammering right along until you've reached a 100% record in those *extra* $100 —or better—bonds!

And while you're at it, now's a good time to check those special cases—*growing more numerous every day*—where increased *family* incomes make possible, *and imperative,* far greater than usual investment through your plant's Pay-Roll Deduction Plan. Indeed, so common are the cases of two, three, or even more, wage-earners in a single family, that you'll do well to forget having ever heard of '10%' as a reasonable investment. Why, for thousands of these 'multiple-income' families 10% or 15% represents but a paltry fraction of an investment which should be running at 25%, 50%, or more!

After the way you've gone at your wartime *production* quotas—and topped them every time—you're certainly not going to let anything stand in the way of your plant's breaking its quota for the 4th War Loan! Particularly since all you are being asked to do is to sell your own people the finest investment in the world—*their own share in Victory!*

LET'S ALL BACK THE ATTACK!

This space contributed to Victory by

The American Society for Metals

This is an official U. S. Treasury advertisement—prepared under auspices of Treasury Department and War Advertising Council

Substitute Alloy for Bronze Worm Gears*

IN THE DEPARTMENT headed "War Products Consultation" in *Metal Progress* for July 1942, page 61, was contained a request from a manufacturer of gear drives (Hamilton Gear & Machine Co. of Toronto) for help in searching for a tin-free substitute for chill-cast nickel-phosphor bronze containing 11% tin, used by that firm for worm gears in heavy duty drives. A satisfactory substitute, later recommended by Chester B. Hamilton, president of the firm, contained 8% antimony, 2% nickel, balance copper, deoxidized with 2 lb. per hundred of 15% phosphor copper. Such material, sand cast in large gears, was reported to have 19,000 psi. yield, 31,900 psi. ultimate and 7.5% elongation. Break-down tests in gear sets running under heavy overloads show it to be just about as good as the conventional phosphor bronze. (See "Critical Points," *Metal Progress*, Aug., 1943, p. 264.)

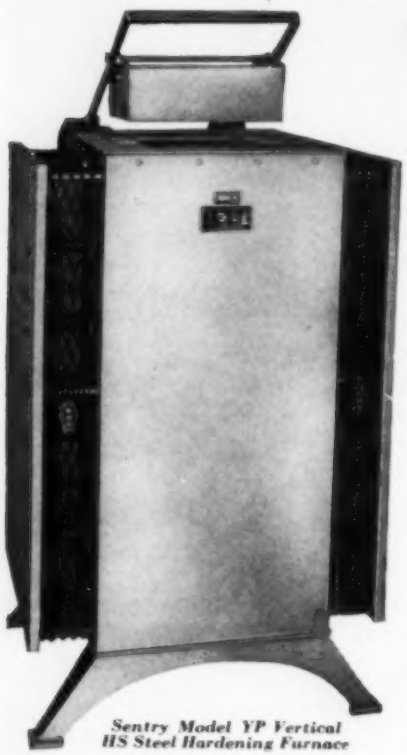
The British Admiralty felt that such an alloy might also be used in other ways and asked for a report on *(a)* production data and how the alloy would behave in the foundry, and *(b)* some indication as to the value of the alloy in service. Several foundries in Great Britain thereupon made and tested experimental melts, data from which follow.

Published equilibrium diagrams of the copper-antimony system, and the same with 2½% nickel, indicate that an alpha solid solution contains up to 10½% antimony at 1225° F., but that solubility is only about 5% at room temperature, the second or beta constituent being (possibly) an intermetallic compound with excess alpha in solid solution. This indicated the possibility of strengthening by heat treatment, which was in fact done.

The alloy was found to have good founding properties — much like 90:10 tin-bronze. It is well to melt with nickel oxide; in any event, this alloy is prone to gas absorption, and this can be best prevented by an oxidizing atmosphere during melting. Zinc, 0.5%, prevents gas absorption (as in gun metal); it is recommended to melt quickly in slightly oxidizing atmosphere, withdraw when melted, deoxidize with phosphor copper and pour at 2140 to 2210° F. Contact with charcoal should be avoided, as far as possible. It has been found even with this method that "stewing" burns out the zinc and "gassing" then tends to occur, especially in natural draft furnaces where the atmosphere will vary in composition. This is the reason why the use of oil-fired forced-draft furnaces is preferred whenever possible.

A number of small castings were successfully made with this alloy, and there is nothing to indicate that the methods of molding and running need be any different from those adopted for normal tin bronzes. *(Continued on page 314)*

*Abstract of Report by Non-Ferrous Technical Committee, Institute of British Foundrymen, *The Metal Industry*, July 23, 1943, p. 50; July 30, p. 74; August 6, p. 86; August 13, p. 105.



Sentry Model YP Vertical HS Steel Hardening Furnace

STRAIGHT!
HARD!
CLEAN!

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Use a **Sentry Vertical H. S. Steel Hardening Furnace** and **The Sentry Diamond Block Method** to assure . . .

• **STRAIGHTNESS**
• **HARDNESS**
• **CLEANLINESS**

Designed especially for Long and Large tools that are best hardened in a Vertical Suspended Position. Three sizes, with tool capacities up to 4¾" Diameters and 36" Lengths.

Built for Sentry Diamond Blocks with Sentry Operating Economy . . . Sentry Speed of Heating . . . Sentry Reliability.

Bulletin 1023-3A Gives Details

Sentry — Always on Duty

The Sentry Company
FOXBORO, MASS., U. S. A.

Axis Tanks—BEWARE!

THIS little lady is preparing bad news for the Axis. She's helping to turn out land mines—and thanks to Mallory, and to resistance welding, she's doing the job *better* and *faster* than it's ever been done before.

Actually, this operator is welding a seam around the perimeter of the mine case. Notice those Mallory resistance seam welding wheels in the picture. Due to the fact that they're made of Mallory 3 Metal, and that they're used in conjunction with immersion cooling, at least three highly desirable results are accomplished:

First, the welds are strong and completely gas-tight. Second, excess warping is avoided and dimensional stability is maintained. Finally, there's very little time wasted redressing and maintaining the electrode wheels. Mallory 3 Metal reduces such "down time" to the minimum.

In scores of other war plants—and in hundreds of different applications—Mallory resistance welding electrodes and Mallory "know how" are producing stronger, lighter, more easily fabricated products at lower cost and in faster time. Mallory engineering can help you too—whether yours is a problem of welding non-ferrous metals in similar or dissimilar combinations . . . or whether your method of production requires spot, flash, butt or seam welding. Write today for your copy of the Mallory Resistance Welding Data Book.

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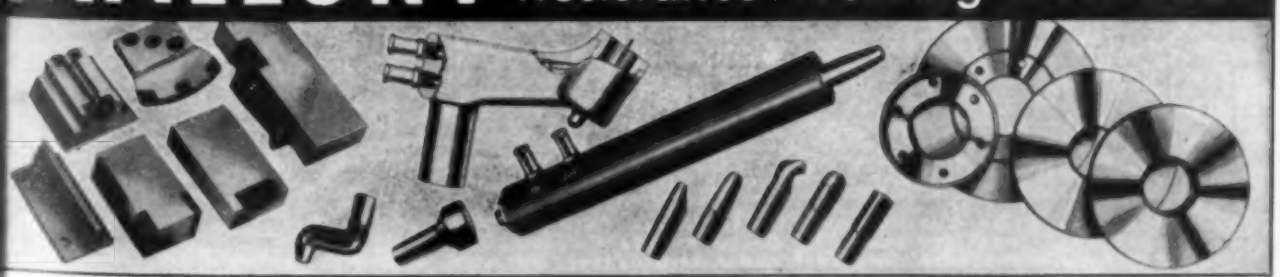
MALLORY *Standardized Resistance Welding Electrodes*



Substitute Bronze

(Continued from page 312)

Due to its long freezing range care must be taken to insure rapid solidification in order to obtain good bearing properties and sound castings.

Tests reported by the British foundrymen showed it difficult to get the reported physicals from standard test bars, sand cast. Average results are as shown at right.

Ultimate strength can be increased 4000 psi. by a precipitation treatment: 4 hr. at 850° F. and air cooling. Elongation values are simultaneously cut almost in half.

Chill casting tended to increase the tensile strength but to reduce elongation and impact values. Test pieces cut from a centrifugal-cast gear gave 26,000 psi.; 31,500 psi.; 3%, 101, and 1 to 2 ft-lb. in the tabulated order.

Average Physical Properties

Yield point	20,000 to 24,000 p
Ultimate	28,000 to 30,000
Elongation	6 to 8% in 2
Brinell hardness	73
Izod test	3 to 6 ft-lb.

Machining is quite good, too lasting a little longer than with t bronzes. This alloy is read repaired by electric arc weldi methods using copper-tin flux-co ered electrodes. Several sand ca bushes were machined and su jected to a tinning operation wi perfectly satisfactory results.

Hamilton Gear & Machine found no advantage in chilling th alloy, and the British experimente confirm that chill casting does n effect much improvement if nickel is present. In fact th copper-antimony alloy witho nickel is much inferior in bo sand and chill castings.

Tramp alloy scrap will not har phosphor bronze or gun meta since they have a considerable to eration for antimony; however, must be rigidly excluded fro brasses and manganese bronzes.

Several friction tests were ca ried out by one investigator on reciprocating motion machin which has been used for man years and gives useful informatio on problems relating to pump pra tice. The alloy was rubbed 100,00 strokes against a carbon steel in th fully hardened condition (Vicker 740) without lubrication, with load of 50 psi., at a speed of 160 f per min. The antimony allo showed a wear of 0.003 in., whil Admiralty gun metal showed wear of 0.089 in.

Microstructure — Two phase are very prominent. First, a core structure similar to that in bronz probably an alpha solid solution copper-antimony and nickel. A low magnifications it is light faw in appearance through which dimly seen the coring.

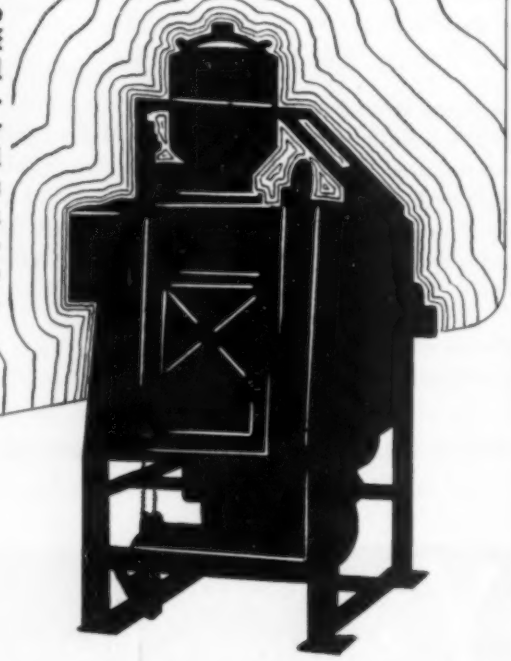
The second main constituent dispersed blue islands of a bet solid solution containing approx mately 35% antimony, surrounde by the cored alpha solid solution This beta phase is definitely th hard bearing constituent. Ther are therefore all the attributes of typical bearing alloy present, fairly soft and yielding matri included in which are isolated par ticles of a hard bearing compoun

A third phase sometimes seem to be visible, but perhaps this due to over-etching. The etchin medium is the usual ferric chlorid solution used for brass.

ATMOSPHERE FURNACES

MUFFLE TYPE

These furnaces are designed for the heat treatment of all types of steel in a protective atmosphere. They utilize the refined products of gas combustion as a protection atmosphere to minimize scaling and decarburization.



TATE-JONES & CO. INC. · LEETSDALE (Pittsburgh District) PA.

Rotating Hearth, Car Bottom, Pusher, Conveyor, Roll Down, Horizontal and Vertical Pit, Circular and Rectangular Pot Furnaces. Also Gas, Oil and Combination Burners

How to *prevent* Corrosion

Coat a section of any piece of raw metal with a protective film of Anti-Corrode. Place it out-of-doors, and leave exposed to the elements.

Rain, snow, changing temperature, dust and grime have eaten into and oxidized the unprotected metal. But note surface under Anti-Corrode film—bright and unharmed, in its original state.

CITIES SERVICE ANTI-CORRODE is a safe rust and corrosion preventive that brings amazing results. It is a reliable safeguard against corrosion of metals in any form or state of finish—whether in storage or in transit. Anti-Corrode forms a tenacious, durable film that is impervious to moisture and the more common gases prevalent in the atmosphere. And, since it contains lubricating material, it need not be removed in drawing operations. Anti-Corrode is made in several grades to meet specific requirements and severest tests. It is economical, easy to apply and can be removed with kerosene or any petroleum solvent.

This TEAM Will Save You Money and Materials

Recently, we announced the development of Cities Service Rust Remover, and responses to the demonstration offer far exceeded our expectations. Rust Remover, of course, *removes* rust. Anti-Corrode is designed to *prevent* rust and corrosion. Together, they will safeguard your equipment and war production—for the duration!

Take advantage of this FREE ANTI-CORRODE demonstration offer
Mail this coupon today!

(Available only in Cities Service marketing territory EAST of the Rockies.)

CITIES SERVICE OIL COMPANY
NEW YORK · CHICAGO

ARKANSAS FUEL OIL COMPANY
SHREVEPORT, LA.

CITIES SERVICE OIL COMPANY
Room 136, Sixty Wall Tower, New York 5, New York

Gentlemen: I would like to test Anti-Corrode on my own equipment FREE OF CHARGE. Please send me the details.

Name_____

Company_____

Address_____

City_____ State_____

. . . in World-Wide Aerial Warfare!

★ Pygmies in size, but giants in achievement are WILCO Thermometals (thermostatic bimetals) and WILCO Electrical Contacts.

★ Either paired with the correct WILCO Thermometal, or used alone, WILCO Aeralloy Aircraft Magneto Contacts are doing their part to assure *smooth* airplane performance. Other WILCO Electrical Contacts are giving equally dependable service in tank, ship and gun applications.

★ WILCO Thermometals, either separately or in conjunction with WILCO Electrical Contacts, are being used with the same success for aircraft oil temperature control and in various instruments for the Army and Navy.

BOTH AVAILABLE FROM ONE SOURCE

★ The facilities of THE H. A. WILSON COMPANY permit manufacturing customers to secure both electrical contacts and thermostatic bimetal from a single source. This is important because materials from these two groups are frequently used in conjunction, as parts in the same device. The most effective use of one necessitates a knowledge of the other. WILCO sales and engineering representatives are familiar with both Electrical Contact and THERMOMETAL application. Send us your problem for analysis.

WILCO PRODUCTS ARE: *Contacts* — Silver, Platinum, Alloys, Powder Metal. *Thermostatic Metal* — High and Low Temperature with Electrical Resistance from 24 to 530 ohms per sq. mil.-ft. *Precious Metal Collector Rings* for rotating controls. *Jacketed Wire* — Silver on Steel, Copper, Invar, or other combinations requested.

THE H. A. WILSON COMPANY
105 Chestnut St., Newark, N. J.
Branches: Chicago ★ Detroit

WILCO

Weldability

(Continued from page 304) as was found in t illustration given cannot always be expecte nevertheless, the tables will undoubtedly exceedingly valuable for "desk work" in a p liminary study of any new design in any n material. Likewise, the tabulations can be u lized for the solution of other problems. T Lehigh tables require that the geometry of t weld and the process be given. The factors th may or may not be known are the material a the ductility; for this an assemblage of Jomi curves and corresponding ductility tests, as w as industrial experience and judgment, are ve helpful. Thereupon the current, voltage a speed may always be determined.

In addition to the class of problem show above, factors in other problems might be follows: Given the geometry, process and mat rial, to find the ductility and the procedur given the geometry and the process, to find th ductility, material and procedure. Another inhe ent value of the system is the opportunity f checking individual heats of steel against expecte performance merely by running the Jominy en quench test and a series of bend tests.

Conclusion

In retrospect, it is apparent that "weld ability" still eludes a quantitative measurement except as the inverse of hardenability. Perhap it does not need re-emphasis that a successfu welded structure — bridge, ship, gun mount pressure vessel or whatever — is something mor than a series of well-made welds in ductile steel Even when attention is focussed on a single joint in a successful structure, it is found to be th complex result of dozens of factors. Separating those factors which have to do with the welding process, equipment, supplies and operator from those which have to do with the response of the base metal to heat and stress, we are at last able to get a clearer view of what "weldability of base metal" means. Experience and logic both indicate that any steel alloy which can be forged or rolled into useful metal has the inherent characteristics which enable it to be joined by fusion welding. In other words, all constructional steels are weldable. The recent work by Hess at Rensselaer and Doan at Lehigh has at last fixed quantitatively the relation between the heat input of arc welding and a predictable effect on hardness and ductility of the base metal alongside the fusion zone. This is indeed a notable advance.

INDUSTRIAL FURNACES AND SPECIAL MACHINES

to improve

Your **POST WAR** *Product*

Custom Built by Continental

To their quarter century's experience in the design and installation of industrial furnaces and special machines, Continental engineers add the new, invaluable knowledge gained in meeting war's exacting demands.

Already they are at work applying this new knowledge to the improvement of peacetime products, both in the plan stage and in actual production.

Through the Continental principle of engineering each heat treating application to the specific job to be done, these products will achieve the life, efficiency and economy so necessary in Post War markets.

Whether your heat treating problems involve ferrous or non-ferrous metals, large jobs or small, put your specifications up to Continental.

BEN FRANKLIN SAYS:

"Look before or you will find yourself behind"

A look ahead now will put you a long step ahead when the break comes. Have Continental help put your Post War heat treating plans into reality.

Custom Built by Continental

CONTINENTAL

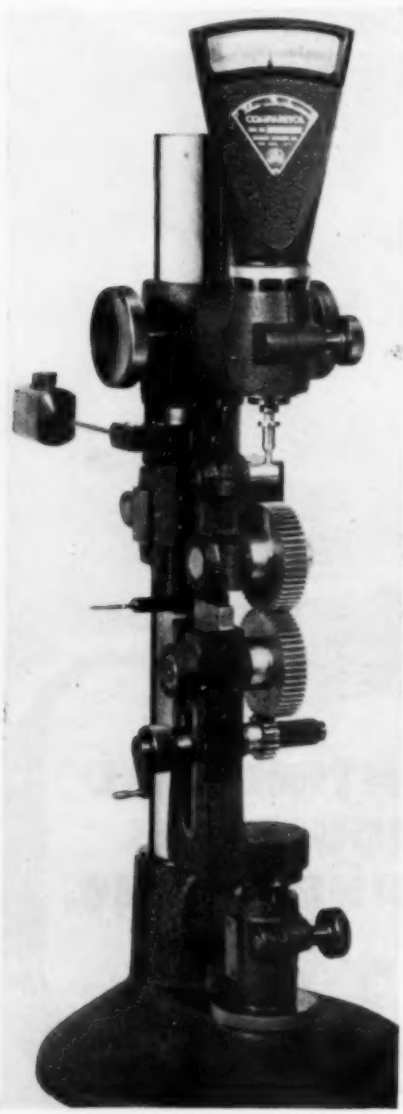
CONTINENTAL INDUSTRIAL ENGINEERS INC.

176 W. ADAMS STREET
CHICAGO, ILLINOIS

New Products

New Gear Test

The inspection of precision gears, for the detection and location of faults during manufacturing, is facilitated in the "Comparitol Gear Tester" offered by George Scherr Co , Inc., New York. The instrument occupies but little bench space and is portable. It employs the highly sensitive, head mechanism widely used on the standard type Comparitol. Illustrated below.

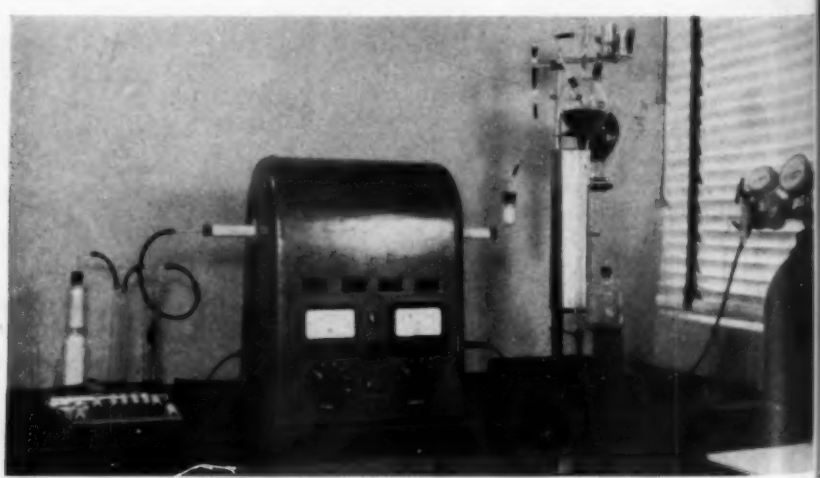


Silver Babbitt

New silver babbitt metal is now being produced by National Bearing Metals Corporation, St. Louis, with the authorization of the Battelle Memorial Institute of Columbus, Ohio. The Institute carried on a research to find a bearing metal comparable to strategic tin-base babbitts and the answer is said to be found in silver alloyed with a properly balanced lead-base babbitt.

Laboratory Furnace

In announcing their new combustion train for the laboratory, Lindberg Engineering Co., 2444 W. Hubbard St., Chicago 12, Ill., calls attention to its combined utility and the modern, streamlined furnace design. The CF-1, so-called, is a single tube furnace, designed for fast carbon and sulphur determinations, as well as gravimetric determination of carbon in all alloy steels including stainless and heat resisting steels. Temperatures obtainable for continuous operation are up to 2500° F. while for occasional operations temperatures up to 2650 are permissible.

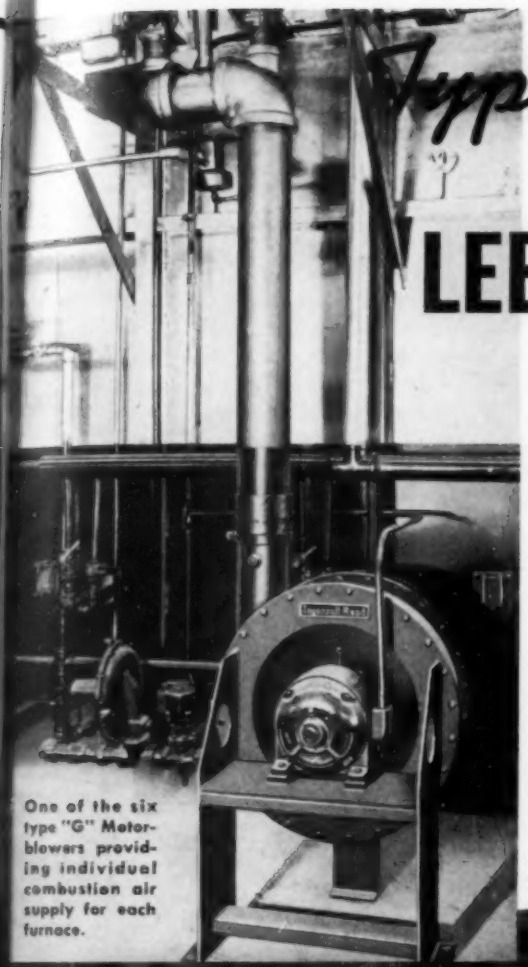


Searchray

Searchray Model 150, second i a series of self-contained X-r units for industry, is announced b Industrial Electronics Division North American Philips Co., Inc 100 E. 42d St., New York City

(Continued on page 332)

Type "G" MOTOR BLOWERS with LEE WILSON FURNACES



One of the six type "G" Motorblowers providing individual combustion air supply for each furnace.

Blowers may be small, but they certainly are not an insignificant part of this battery of heat-treating furnaces which the Lee Wilson Engineering Co., Inc. of Cleveland, Ohio installed in a southern munitions factory.

Combustion air *must* be dependable, otherwise a complete furnace may be shut down at any time. . . . Type "G" Motorblowers have earned the reputation of giving the reliable and trouble-free service that makes possible long, continuous production records.

Specify Type "G" MOTORBLOWERS

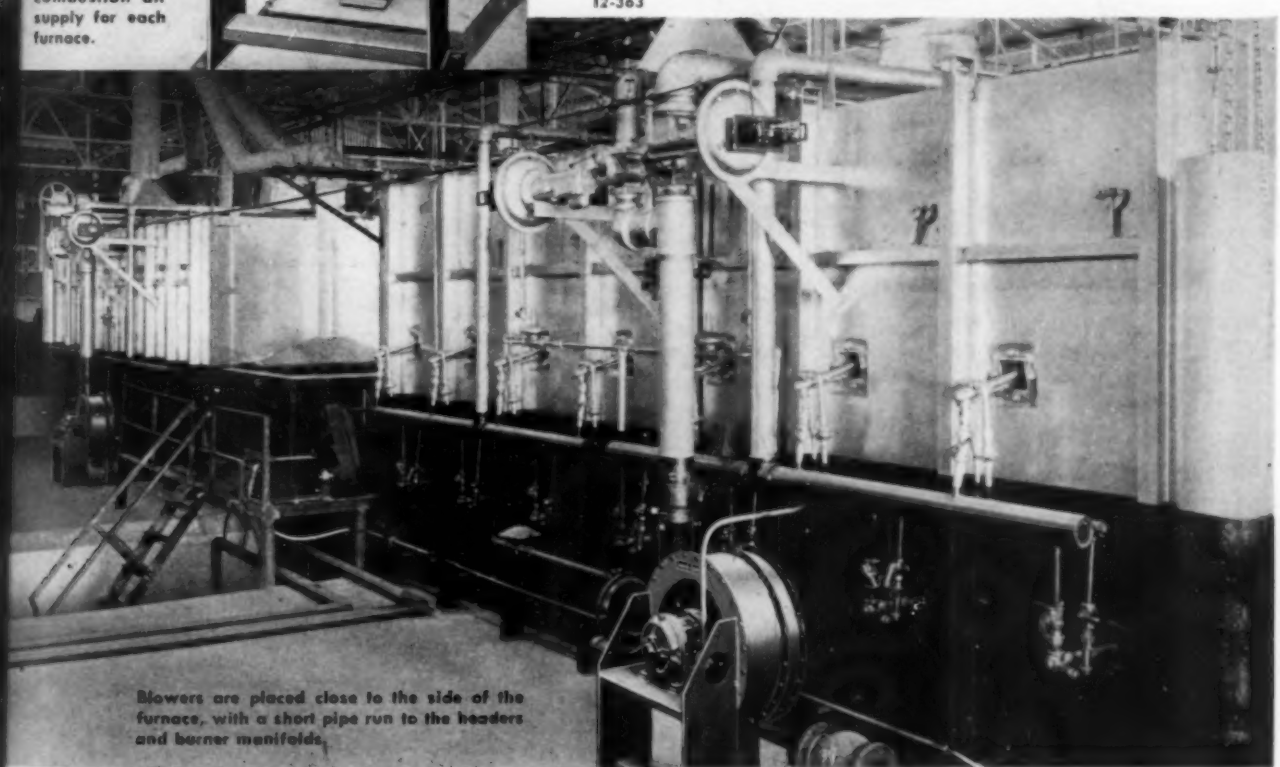
PRESSURE: ½ to 2¼ lb. POWER: 2 to 30 hp.
VOLUME: 100 to 4500 cfm. BULLETIN: Form 2671-B.

Turbo Blowers up to 14500 hp.

Ingersoll-Rand

11 BROADWAY, NEW YORK 4, N. Y.

12-363



Blowers are placed close to the side of the furnace, with a short pipe run to the headers and burner manifolds.

COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO BLOWERS • CONDENSERS • CENTRIFUGAL PUMPS • OIL AND GAS ENGINES

WHAT FLUX is BEST . . .

for Welding Silicon Bronzes? Silver Soldering or Gas Welding Stainless?

Get the answers to these and hundreds of similar questions from the Krembs Fluxine Chart . . . . new, revised edition just published. Explains how to select the proper flux for every metal-joining job. Easy to use. Handy for reference. Prepared by consulting, welding and brazing engineers, originators of 89 different non-bubbling, quick flowing Fluxine Fluxes. Chart free when requested on a company letterhead.

KREMBS AND COMPANY
672 West Ohio Street Chicago 10, Illinois
CHEMISTS AND METALLURGISTS SINCE 1875

FLUXINE
TRADE MARK REGISTERED U.S. PAT. OFF.
FLUXES TO JOIN ALL METALS

ZIVSTEEL

TOOL & DIE STEELS

May we help you select suitable types of steel for your Victory tool and die program?

Write or phone

ESTABLISHED 1911
ZIV STEEL & WIRE CO.

High Grade Tool Steel

Chicago — Detroit — Indianapolis — Milwaukee
St. Louis — Calumet, Mich.

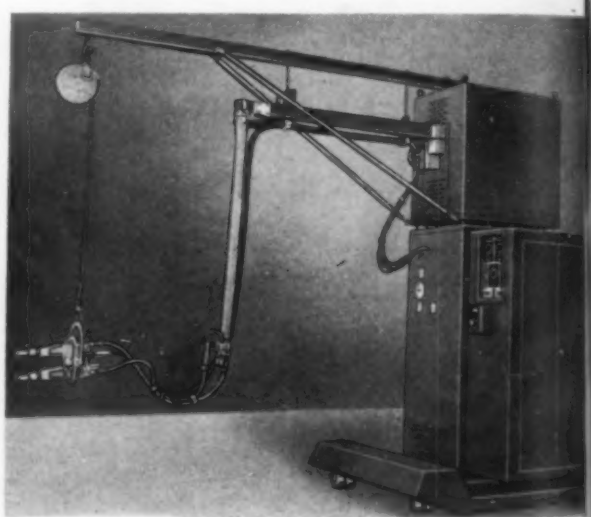
New Products

(Continued from page 330)

This inspection instrument makes the highest quali sharp radiographs, and, according to the manufa turer, is usable by ordinary plant personnel und standardized and controlled conditions, without t expense of a skilled X-ray technician or the cost of lead-lined room.

Portable Spot Welder for Aluminum

Crowded and fixed jigs can be easily reached wi this new portable welder, specially designed for al minum and light alloys by Sciaky Bros., Chicago 3



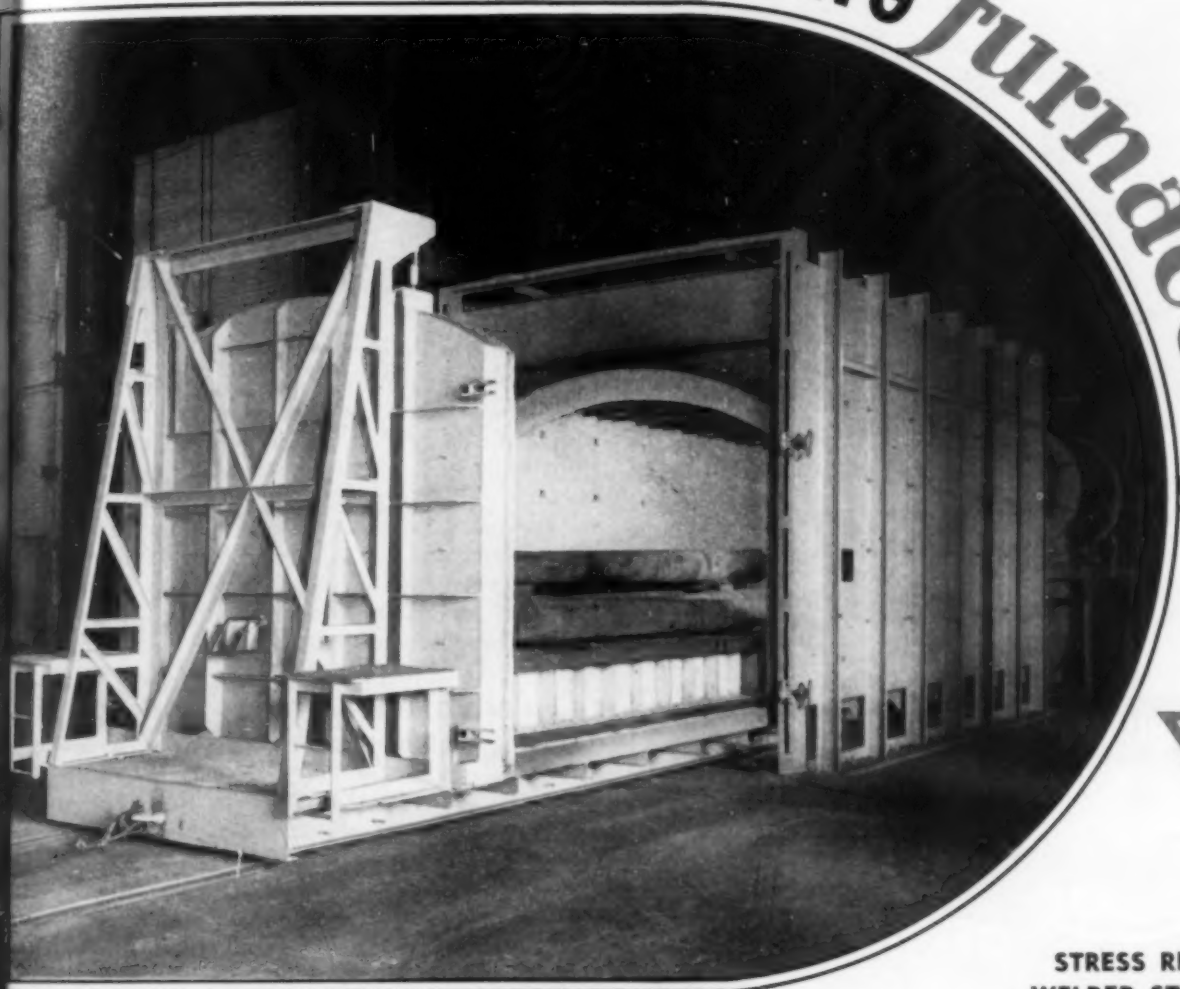
Ill. Tacking operations as well as structural weldin on large or fixed aluminum structures can be accom plished with greater speed and efficiency, it is said. Welder is rated at 100 kw. and can handle aluminum sheets in two thicknesses of 0.016 up to 0.064 in., c corrosion resisting steels in two thicknesses of 0.01 up to 0.080 in.

Standard Box-Type Oven

Standard box-type ovens in several sizes for a variety of batch heating purposes, are now produced by Industrial Oven Engineering Co., 11621 Detroit Ave., Cleveland. It uses any commercial fuel (including electricity). Door sizes range from 3 ft. by

(Cont. on page 334)

RECIRCULATING GAS TYPE CONVECTION HEATING *Furnaces for*

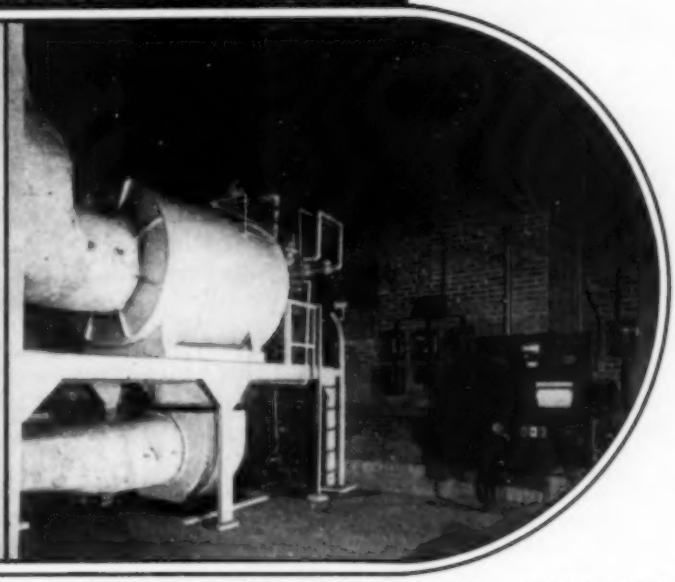


A TYPICAL WILSON INSTALLATION

STRESS RELIEVING FURNACE FOR HEAVY SHAFTING AND WELDMENTS

•

GAS HEATERS AND RECIRCULATING FANS COMPLETE AUTOMATIC TEMPERATURE CONTROL OF HEATING, SOAKING AND COOLING



STRESS RELIEVING WELDED STRUCTURES, CASTINGS, OR FORGINGS

MINIMUM TEMPERATURE SPREAD

RAPID HEATING

WIDE TURNDOWN RANGE

ACCURATE REPETITION OF CYCLES

LOW FUEL RATES

HIGH RECIRCULATING VOLUMES

The Wilson Annealing Unit is covered by Patents Nos. 1,952,102, 2,068,477, 2,079,356, 2,081,612, 2,088,813, and other patents pending.

ENGINEERED AND CONSTRUCTED BY THE

Lee Wilson ENGINEERING Co., Inc.

20005 West Lake Road CLEVELAND, OHIO

Telephone ACademy 4670

INDUSTRIAL FURNACES • RADIANT TUBE HEATING • HEAT TREATING PROCESSES

Checks tensile strength of steel, aluminum, wire, plastics, special shapes, many others. Readily adaptable to compression or transverse testing.

Fast acting, self-aligning grips for flat or round specimens. Machine equipped with ball bearings throughout.

Seven different capacities ranging from 0-250 lbs. up to 0-10,000 lbs. Maximum hand. Instrument not injured by accidental overload.

Light weight — fully portable. For production line, laboratory, or field testing. An accurate and reliable instrument.

★ ★

Dillon

TENSILE TESTER

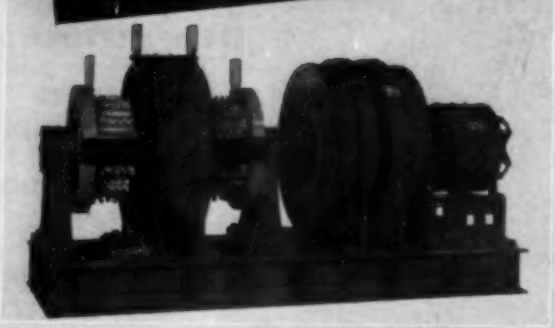
Prominently used by Republic Steel–Douglas Aircraft–Allison Motors–Sperry Gyroscope–etc. Embodies all desirable testing features yet is *low* in cost. Good delivery.

WRITE DEPT. BP FOR LITERATURE

W. C. DILLON & CO., INC. 5410 W. HARRISON STREET CHICAGO, ILLINOIS

COLUMBIA **MOTOR GENERATORS**

for Electroplating and other Electrolytic Processes



Columbia Generators embody every feature essential for dependable, 24-hour operation. They are built for electroplating service in sizes of 6 to 20 volts, 500 to 20,000 amperes, for anodic treatment of aluminum in sizes of 40, 50, and 60 volts, 500 to 3,000 amperes. Columbia Generators for other electrolytic processes range from ½ to 250 KW, 100 to 40,000 amperes, 6 to 60 volts.

Prompt shipment can be made on any type and size. Write for full information.

COLUMBIA ELECTRIC MFG. CO.
4519 Hamilton Ave., N. E. • Cleveland 14, Ohio

New Products

(Continued from page 332)

5 ft. high to 5 ft. wide by 7 ft. high. Working depth are from 4 to 10 ft. Close temperature control within limits from 200 to 1000° F. is featured.

Powder Metal Press

Developed especially for high-speed production of powdered metal parts, pieces up to 3 in. diameter with a die-fill of 2⅝ in. are compressed at rates of 15 to 45 in. per min. by press made by F. J. Stokes Machine Co., Philadelphia. Pressures up to 20 tons are applied from both top and bottom and pressure adjustments may be made while press is operating. Thus density of the piece produced may be controlled with great exactness, to assure uniform electrical and mechanical characteristics.

Liquid Bath Thermocouple

New vent-type thermocouple has been developed by the Claud S. Gordon Co., 3000 S. Wallace St., Chicago. Vent at top permits gas to escape and, by artificial circulation, admits the right amount of pure air to take its place, thus avoiding one of the chief difficulties experienced in obtaining satisfactory life of tubes and thermocouples used in liquid baths such as cyanide and salts, thought to be the contamination of the thermocouple by trapped gases within the protecting tube.

Finish for Zinc Surfaces

Process said to produce an even, black and corrosion resistant finish on zinc or zinc alloy surfaces, known as the Alronox Process, is announced by the Alrose Chemical Co., Providence, R. I. No elaborate equipment or controls are necessary; process can be applied within a 7-min. cycle. It is non-electrolytic and has a salt spray rating of 200 to 300 hr. on 0.0002 zinc plate over steel, without the aid of after-coatings.

Production Line X-Rays Use Miniature Film

Using a high-speed camera to make 2-in. film negatives (instead of standard larger sizes up to 14 by 17 in.), a radiograph has now been developed that fits into the production line, according to Westinghouse engineers. This machine photographs and proportionately reduces on miniature film the X-ray image shown on a 72-in. square fluorescent screen. About 300 exposures can be made on a single 50-ft. roll of film. In order to adapt the unit to production lines without endangering personnel it is designed so that no special lead-lined surroundings are needed. Made

(Continued on page 336)

DE-BURR MECHANICALLY!

ROTO
THE STURGIS PRODUCTS CO.
STURGIS • MICHIGAN
Trademark Reg. U. S. Pat. Office
FINISH

Roto-Finish is a startling, versatile new process for the mechanical de-burring, grinding, honing, buffing, and coloring of metal parts. Using a revolutionary adaptation of the tumbling process, Roto-Finish successfully finishes *steel*, *brass*, *aluminum*, *stainless* and *nickel steels*. It can be varied from a rough grinding action to the finest finishing.

Dozens of the large war producers report savings up to 96% over hand finishing methods. Roto-Finish is being used on castings up to 75 pounds down to small, delicate, intricate parts a fraction of an ounce. Hundreds of small parts can now be finished in a fraction of the time required before. Write for complete information, or send samples to be processed, without charge.

THE STURGIS PRODUCTS CO.

239 JACOB STREET, STURGIS, MICHIGAN

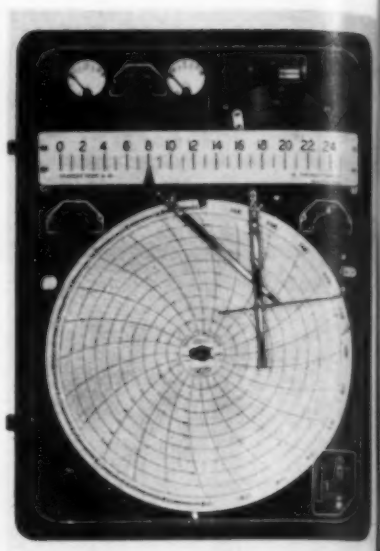
New Products

(Continued from page 334)

in two sections, the water-cooled X-ray tube is contained in the protected upper head which is automatically controlled. This head must telescope and fit exactly with the lower section before an exposure can be made.

New Model Pyromaster

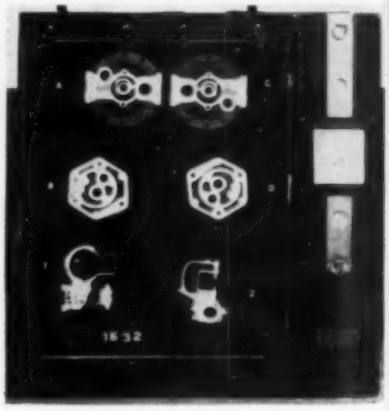
Redesign of "Pyromaster" self-balancing potentiometer is announced by The Bristol Co., Waterbury 91, Conn. New model 431 has a universal wall or flush mounting case, considerably deeper than the previous model 440M, and an internal hinged panel on which are mounted pen and indicator drive mechanism shown in the view (front cover swung back). In the electric controllers, the control contacts or proportioning slide wires are also on the hinged panel



— as is also the type of construction in the air control, the complete new convertible-type air operated control mechanism. This new deep case and inner panel make it possible to service any part without disturbing any other part of the mechanism.

High Intensity X-Ray Illuminator

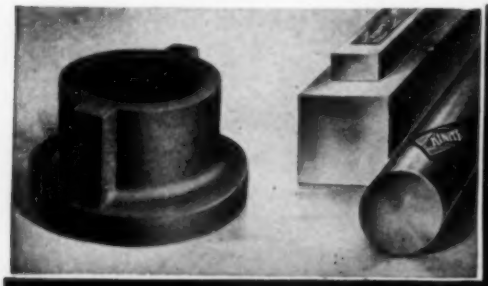
Providing four times more illumination than heretofore available, this new X-ray illuminator reveals



film detail formerly missed with weaker light sources, according to the Kelley-Koett Mfg. Co., 212 W. 4th St., Covington, Ky.

All-Weather Welder

AC welders, in all-weather models of 300 and 500-ampere capacities, are announced by Wilson Welder and Metals Co., Inc., 60 East 42nd St., New York 17. These machines are similar to the standard "Bumblebee" AC welders, except they have special moisture-proof insulation and all parts are protected by a heavy coating of moisture-proof paint.



KINITE

THE STEEL WITHOUT AN EQUAL

KINITE is in the high carbon chrome alloy tool steel air hardening class.

An analysis all of its own . . . .
Its characteristics:

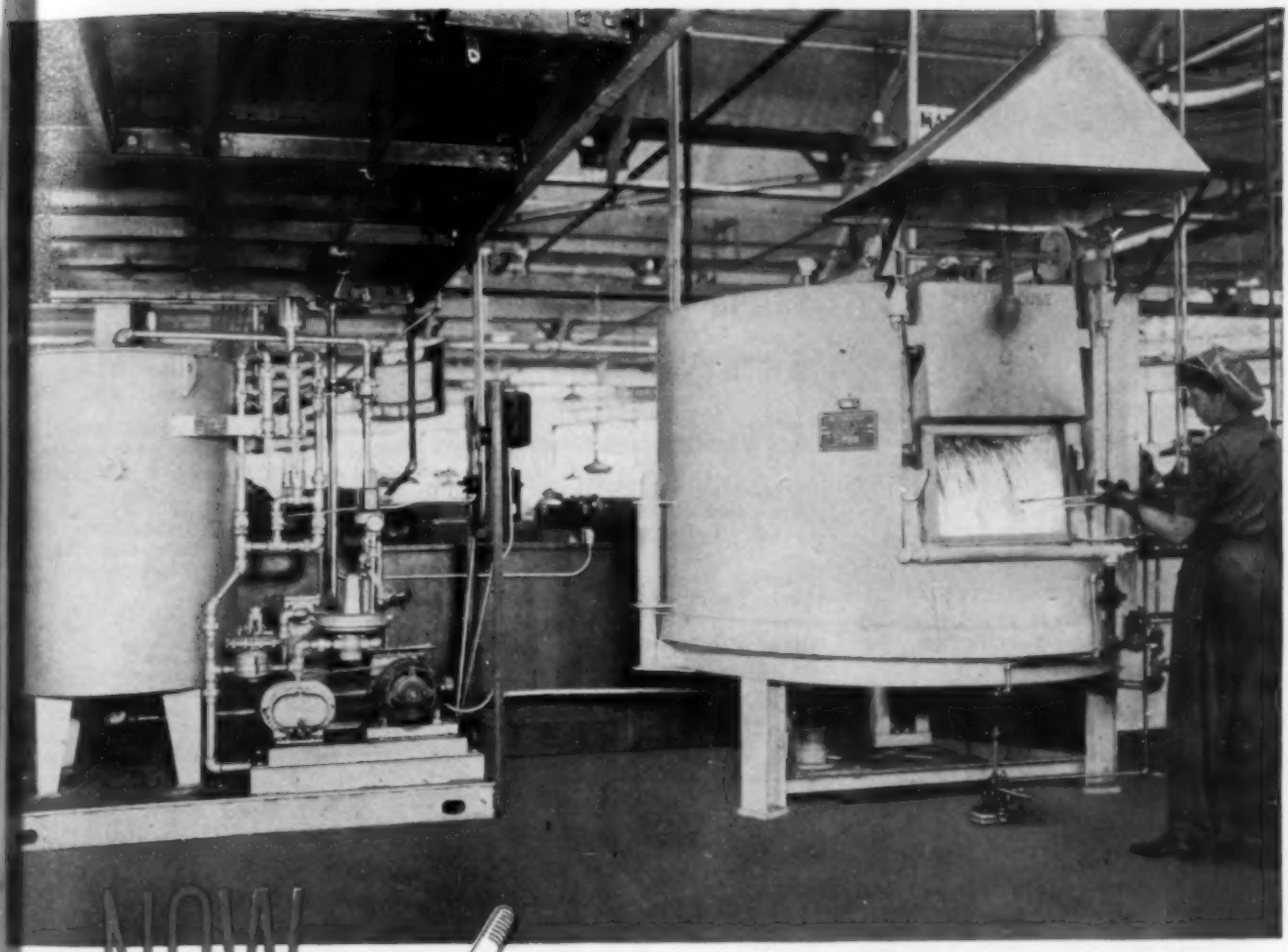
1. Increases production.
2. Reduces grinding and retooling time.
3. Resists wear and abrasion.
4. Excellent machinability.
5. Minimum distortion.
6. Fine heat treatability.
7. Immune to cracking during heat treatment.
8. In bar stock or castings.

KINITE alloy air hardening steel offers an unusual combination of features never before found in a steel of this type.

Pamphlets on request.

EST. BOKER 1837

H. BOKER & CO., Inc.
101 DUANE ST. • NEW YORK



NOW

A NEW ROTARY HEARTH FURNACE

for parts requiring Individual Handling, No Scale, No Decarb

Westinghouse announces a new Rotary Hearth Furnace for heat-treating parts that require individual handling. The furnace when used with Endogas protective atmosphere keeps parts free from scale and decarb.

This new Type RB-50 furnace provides a convenient method for handling parts that must be fixture quenched. It is designed for hardening of machined parts, such as gears and shafts; hardening of small parts loaded in trays; heating for normalizing or drawing.

The new Westinghouse Type RB-50 furnace not only assures uniform hardness and scale-free work but also increases production. Parts are charged and unloaded from the same point. The heating cycle is automatically controlled by a time clock. A bell alarm tells the operator when to discharge. For further details on this simple, economical, easy method of continuous heat-treating, call our Westinghouse office. Westinghouse Electric & Manufacturing Co., East Pittsburgh, Penna.

J-10258

Westinghouse

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

Complete HEAT TREATING EQUIPMENT

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Wall charts and manual sheets by Firth-Sterling Steel Co. make easy the selection of color-branded sintered carbides for cutting tools. Bulletin 391.

Marvel metal cutting saws. Armstrong-Blum Mfg. Co. Bulletin 395.

16-page booklet features 22 short stories of how proper cutting fluids have solved production problems. D. A. Stuart Oil Co. Bulletin 403.

Automatic profilers and hydraulic benders. Pines Engineering Co. Bulletin 344.

Powdered metal presses. Kux Machine Co. Bulletin 1.

Forging presses. Ajax Mfg. Co. Bulletin 2.

Horizontal extrusion presses. Hydropress, Inc. Bulletin 3.

36-page pictorial story of the Cecostamp. Cambersburg Engineering Co. Bulletin 4.

Cutting Oils. Cities Service Oil Co. Bulletin 5.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin 7.

Information and data on straightening press. Anderson Bros. Mfg. Co. Bulletin 10.

Properties and uses of cutting oils. Gulf Oil Corp. Bulletin 8.

Surface coated abrasive belts. Minnesota Mining & Mfg. Co. Bulletin 12.

Presses for the metal working and process industries. Hydraulic Press Mfg. Co. Bulletin 20.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin 15.

New catalog illustrates standard, non-standard, and special tools. Kennametal, Inc. Bulletin 250.

Mounted wheels, Handee and Hi-Power tools. Chicago Wheel & Mfg. Co. Bulletin 21.

20-page booklet on cutting fluids. Tide Water Associated Oil Co. Bulletin 252.

Air tools in steel mills and foundries are pictured in new booklet by Ingersoll-Rand. Bulletin 255.

Big, comprehensive catalog illustrates line of power presses offered by Minster Machine Co. Bulletin 320.

Complete and valuable study "Machining of Metals", including chip formation, is offered by National Refining Co. Bulletin 335.

Parsons oval bag dust arrestor Parsons Engineering Corp. Bulletin 228.

Lubricoolant, a new type of coolant said to prolong tool life on materials from chrome-molybdenum steels to aluminum alloys, is described in new leaflet issued by the DuBois Co. Bulletin 408.

New leaflet describes the Doall band filing machine. Continental Machines, Inc. Bulletin 430.

Complete summary of new Doall tools is presented in new booklet issued by Doall Service Co. Bulletin 432.

Safe-T tongs and their use in materials handling are described in new booklet by Heppenstall Co. Bulletin 434.

FERROUS METALS

Republic Steel Corp.'s second edition of National Emergency Steels tells you all about these new steels. Bulletin 345.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin 2

Use Handy Coupon Below for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 364, 366, 368, 370, 372, 374, 376, 378, 382, 384, 386, 387, 388 and 390

Metal Progress 7301 Euclid Ave., Cleveland 3, Ohio — February, 1940

Send me the Literature I have indicated below.

Name ..... Title .....

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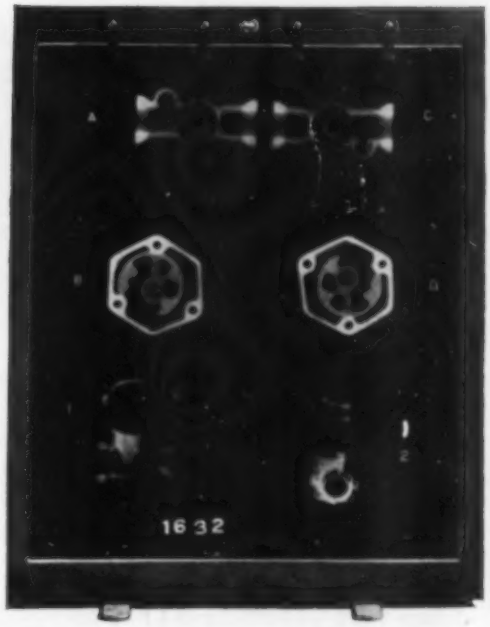
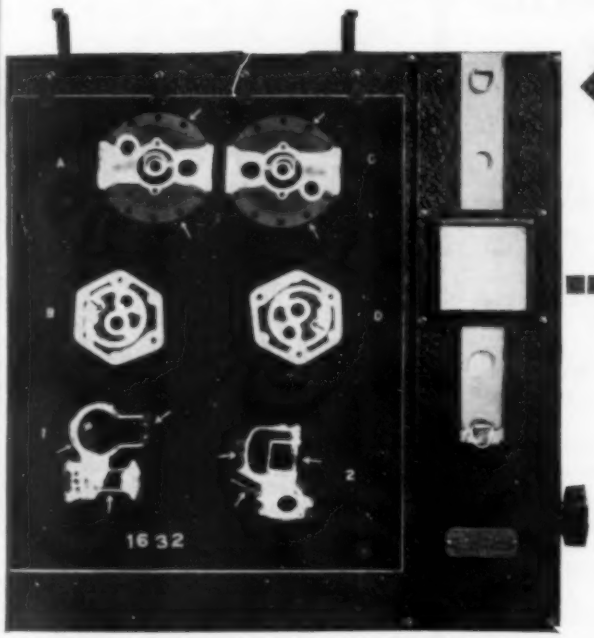
Check or circle the numbers referring to literature described on these 15 pages.

1	40	66	96	120	149	174	202	250	305	335	362	387	413	433
2	41	67	97	121	150	175	203	251	307	337	363	388	414	434
3	42	68	98	122	152	176	204	252	312	338	364	390	415	435
4	43	70	99	123	154	177	206	255	313	339	365	391	416	436
5	44	71	100	124	155	179	207	258	314	343	366	394	417	437
7	45	72	101	128	156	180	208	260	315	344	367	395	418	438
8	47	75	102	132	158	182	210	261	316	345	368	397	419	439
10	48	76	103	133	160	183	212	264	318	346	369	398	420	
12	49	78	105	134	161	184	213	269	319	347	371	399	421	
15	50	79	106	135	162	185	215	270	320	350	372	401	422	
20	51	82	107	137	163	186	217	271	322	351	374	402	423	
21	52	83	109	138	164	189	228	281	323	353	375	403	424	
24	53	84	110	139	165	190	230	284	324	354	376	404	425	
25	56	85	112	141	167	192	232	288	325	355	377	406	426	
26	57	86	114	142	168	193	234	291	327	356	378	407	427	
30	59	89	115	143	169	196	240	292	328	357	380	408	428	
31	60	91	116	144	170	197	241	296	329	358	381	409	429	
33	62	93	117	146	171	199	243	297	330	359	383	410	430	
35	64	94	118	147	172	200	245	299	331	360	384	411	431	
38	65	95	119	148	173	201	246	301	333	361	385	412	432	

What's Wrong WITH THIS RADIOGRAPH?



Not a thing in the world. It's the illuminator that's at fault. An ordinary, run-of-mine illuminator that allows vital detail to remain unseen. And that may permit serious flaws to escape notice. The usual illuminator is seldom adequate for film of more than 1.5 density.



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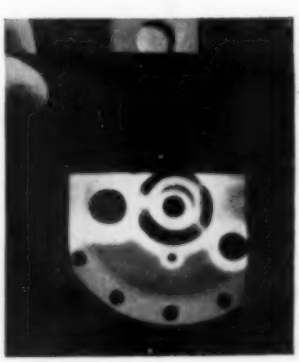

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LITERATURE ON REQUEST

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SCIENTIFIC LABORATORY SUPPLIES

WHAT'S NEW

IN MANUFACTURERS' LITERATU

Page after page of useful technic data and reference tables on to steels. Latrobe Electric Steel C Bulletin 367.

Steel Data Sheets. Wheelock, Lov joy & Co. Bulletin 25.

Molybdenum wrought steel Molybdenum Corp. of America. B letin 26.

Free Machining Steels. Monar Steel Co. Bulletin 30.

Chemical analyses, shapes a sizes of Joslyn stainless steel pro ucts. Joslyn Mfg. and Supply C Bulletin 297.

Tool Steels. Bethlehem Steel C Bulletin 31.

Enameling iron sheets. Inlan Steel Co. Bulletin 33.

Loose-leaf reference book on m lybdenum steels. Climax Molybd num Co. Bulletin 35.

Low carbon open hearth case ca burizing steel. W. J. Holliday & C Bulletin 38.

Aircraft Alloy Steels. Joseph T Ryerson & Son, Inc. Bulletin 40.

Kinite alloy tool steel bar stock. H Boker & Co., Inc. Bulletin 258.

New Catalog C makes it easy to g International Nickel Co. literature, a it presents brief description and in dex to a wide variety of booklets Bulletin 305.

"Graphitic Booklet" gives complete information on new, free-machining long-wearing steel. Steel & Tub Div., Timken Roller Bearing Co Bulletin 307.

Spark Testing Guide—a 21" x 30" wall chart—is useful in segregating tool steel scrap, unscrambling mixed stocks and checking identity of tool steel before heat treatment. Carpenter Steel Co. Bulletin 312.

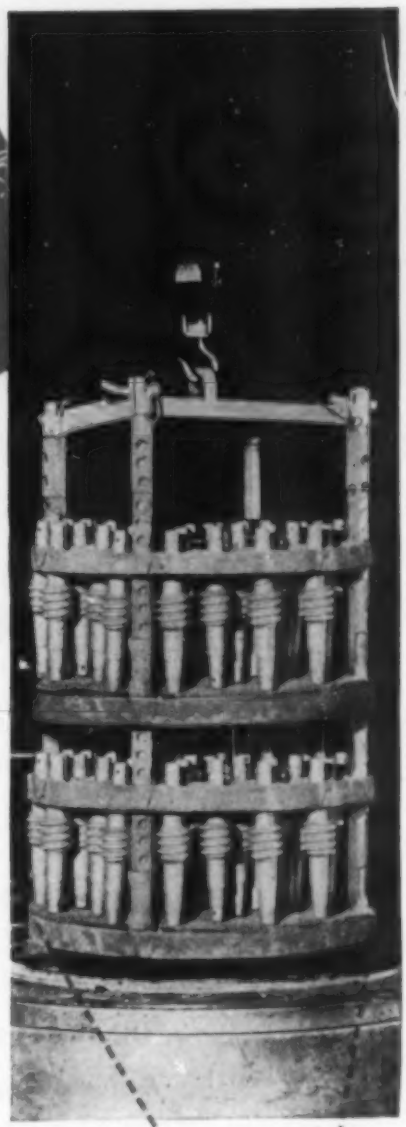
HWD hot work die steel and Ster ling stainless steels are described in four new leaflets by Firth-Sterling Steel Co. Bulletin 323.

Engineering and comparative in formation on porcelain enameled iron is presented in new illustrated booklet by American Rolling Mill Co. Bulletin 376.

New booklet gives full information on N-A-X high tensile and N-A-X 9100 Series of alloy steels. Great Lakes Steel Corp. Bulletin 328.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 366, 368, 370, 372, 374, 376, 378, 382, 384, 386, 387, 388 and 390.



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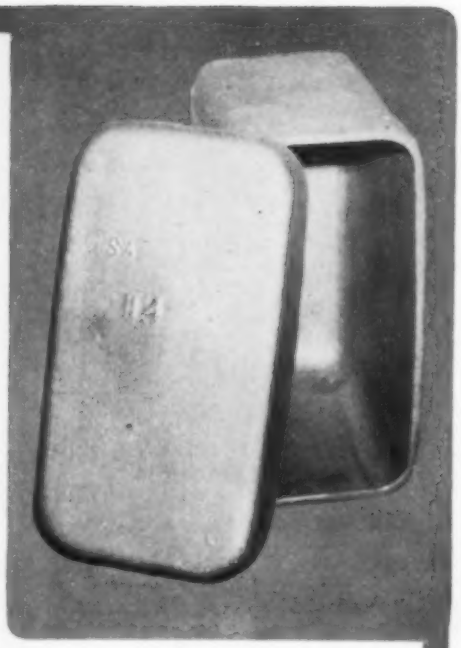

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Spindle speed calculator is hand chart to figure machining rates o bar steels. Bliss & Laughlin, Inc Bulletin 333.

Attractive new catalog describe the line of steel offered by Penin sular Steel Co. Bulletin 337.

64-page booklet describes th welding of stainless steels. Alle gheny Ludlum Steel Corp. Bulleti 384.

Technical data booklet on Mo-Ma steels is offered by Cleveland Twis Drill Co. Bulletin 435.

NON-FERROUS METALS

80-page pipe and tube bendin handbook has been issued by Coppe & Brass Research Assn. Bulletin 39

Platinum Metal Catalysts. Baker Co., Inc. Bulletin 41.

Die casting equipment. Lester Phoenix, Inc. Bulletin 42.

Bronze. Frontier Bronze Corp Bulletin 44.

Copper Alloys. American Brass Co Bulletin 45.

Handy & Harman has issued a re vised edition of their general catalo on Sil-Fos and Easy-Flo brazing alloys. Bulletin 43.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin 47.

"The Story of Magnesium," illustrated booklet by the Permanente Metals Corp. Bulletin 261.

Brass and bronze castings. Hammond Brass Works. Bulletin 48.

Reference on properties of lead. St. Joseph Lead Co. Bulletin 49.

6th edition of Revere Weights and Data Handbook. Revere Copper and Brass, Inc. Bulletin 296.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin 50.

Forgeable tin-free bearing metal. Mueller Brass Co. Bulletin 53.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin 52.

Rare metals, alloys and ores. Foote Mineral Co. Bulletin 56.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 368, 370, 372, 374, 376, 378, 382, 384, 386, 387, 388 and 390.

Introducing

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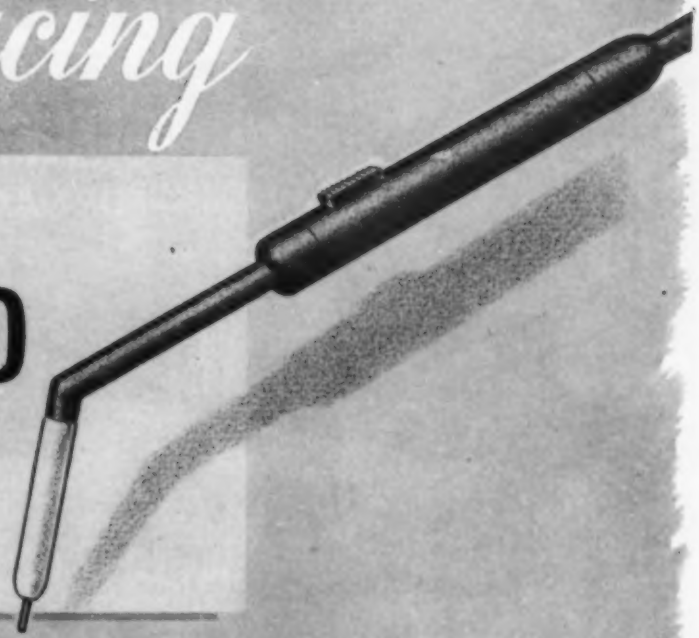
HELIWELD HOLDER



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WHAT'S NEW

IN MANUFACTURERS' LITERATU

Brazing Booklet. Westinghou Elec. & Mfg. Co. Bulletin 57.

Dowmetal data book. Dow Chem cal Co. Bulletin 51.

Two new Ampco Metal data shee discuss forging Ampco to improv physical characteristics and use Ampco for non-scratching feed fi gers. Bulletin 314.

20-page book shows each step i production of brass and aluminu castings by Manufacturers Bra Foundry Co. Bulletin 414.

Aluminum and its importance t product designers is the title of 2 page booklet issued by Reynold Aluminum Co. Bulletin 418.

"Designing with Magnesium" is t tle of new book offered by America Magnesium Corp. Bulletin 433.

WELDING

Welding Stainless. Page Steel Wire Div., American Chain & Cabl Co., Inc. Bulletin 59.

Oxy-acetylene welding and cutting Linde Air Products Co. Bulletin 6

Chart explains how to select prope flux for every welding, brazing an soldering job. Krembs & Co. Bul letin 60.

Flexarc A-C welders. Westing house Electric & Mfg. Co. Bulletin 6

Welding and brazing of aluminum, a new data book issued by Alumi num Co. of America. Bulletin 66.

Data book facts on spot, seam and flash welding ferrous and non-fer rous metals and alloys. P. R. Mal lory & Co., Inc. Bulletin 65.

Shield Arc electrodes. McKay Co. Bulletin 67.

New advances in arc welding equipment design. Harnischfeger Corp. Bulletin 68.

Nu-Braze No. 4, an improved silver brazing alloy. Sherman & Co. Bulle tin 288.

New 12-page booklet tells how to fabricate fittings for welded piping by means of flame-cutting and weld ing. Air Reduction Co. Bulletin 234.

Atomic-hydrogen arc welding, its application and use, is described by General Electric Co. in new Bulletin 241.

32-page catalog describes line of welding equipment offered by Vic tor Epuipment Co. Bulletin 245.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 370, 372, 374, 376, 378, 382, 384, 386, 387, 388 and 390.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New "200" welder is described by Allis-Chalmers in Bulletin 260.

Advantages and physical characteristics of "No-Wear", a hard-facing material. Callite Tungsten Corp. Bulletin 251.

New 500 lb. capacity welding positioner for light welding jobs is described by Ransome Machinery Co. Bulletin 313.

Two new hard-facing alloys furnished as welding rods for application by Oxy-Acetylene process are described by the Stoody Co. in Bulletin 325.

New line of welding positioners with dual capacity are described in new booklet by Harnischfeger Corp. Bulletin 350.

Vest pocket guide to correct welding practices is offered by Hobart Brothers Co. Bulletin 351.

Comparable arc welding electrodes for stainless are shown in chart issued by Alloy Rods Co. Bulletin 353.

Attractive, new booklet describes electric resistance welder for aluminum and its alloys. Sciaky Corp. Bulletin 358.

Helpful electrode color chart is offered by the Arcos Corp. Bulletin 374.

Arc welding inspection chart, designed so that operators can tell at a glance whether welds are being properly made, has been issued by the Lincoln Electric Co. Bulletin 411.

"The Eutectic Welder" is title of monthly publication devoted to welding news issued by Eutectic Welding Alloys Co. Bulletin 412.

Many uses and advantages of Colmonoy hard facing alloys and overlay metals are illustrated in new 8-page folder issued by Wall-Colmonoy Corp. Bulletin 415.

TESTING & INSPECTION

Picker X-Ray Corp. has file of four helpful booklets showing line of X-ray equipment and supplies. Bulletin 402.

Bibliography of more than 700 papers dealing with the polarographic method of metal analysis and a booklet discussing this equipment is offered by E. H. Sargent & Co. Bulletin 338.

Various methods and specific applications of the measurement of case depth are described in illustrated pamphlet offered by Allen B. DuMont Laboratories, Inc. Bulletin 339.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

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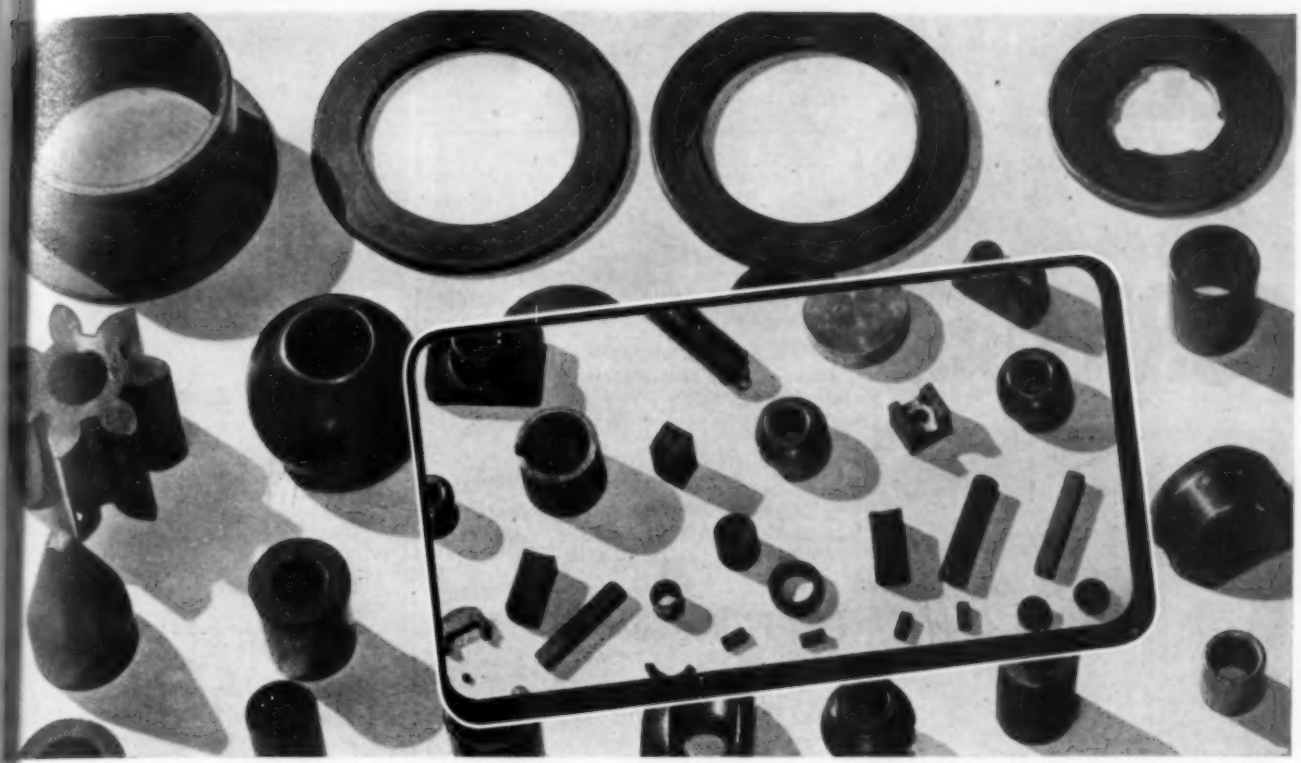

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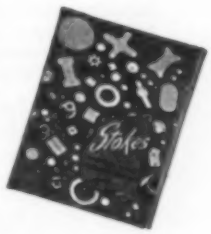

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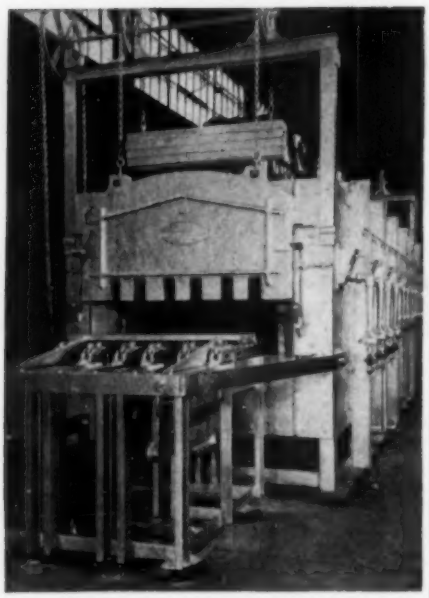

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Metallurgical polishing equipment offered by Precision Scientific Corp. is described in illustrated booklet. Bulletin 359.

SR-4 strain gage and illustrations of its many uses. Baldwin Southwark. Bulletin 70.

New book contains wealth of practical, usable information on industrial inspection by x-ray. Westinghouse Electric & Mfg. Co. Bulletin 71.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin 72.

Electric heaters and controls for industrial and laboratory. American instrument Co. Bulletin 75.

Carbon-Meter for rapidly determining carbon at the furnace. E. Leitz, Inc. Bulletin 264.

Inspection of non-magnetic metals with the new Zyglo method. Magnaflux Corp. Bulletin 78.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin 79.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin 83.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin 85.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin 86.

Dillon tensile tester and the Dillon dynamometer. W. C. Dillon & Co. Bulletin 91.

Optical Aids. Bausch & Lomb Optical Co. Bulletin 94.

Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin 95.

Metallographic polishing powder. Conrad Wolff. Bulletin 96.

Metallurgical Equipment. Adolph I. Buehler. Bulletin 97.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin 98.

Attractive, illustrated booklet describes Clark Instrument's precision hardness tester. Bulletin 318.

"Radiography of Materials" is title of new 96-page book on industrial radiography. Eastman Kodak Co. Bulletin 331.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 374, 376, 378, 382, 384, 386, 387, 388 and 390.

Here's How. . .

WE WIN FRIENDS at Benedict-Miller

Today's allotments, priorities, government reports, etc., often seem to make the job of producing VICTORY unnecessarily difficult. We at Benedict-Miller wish there were simpler means of doing *our* job—for *your* benefit.

For the present, however, it seems as if good old hard work—overtime by *both men* and *machines*—is the best way of our insuring you the continuation of a steel service that is efficient, friendly, helpful—specializing in

Alloy and Carbon Grades . . . As Rolled, Annealed and Heat Treated Machinery Steels . . . Cold Finished and Hot Rolled . . . Tool Steels . . . High Speed Steels . . . Drill Rod . . . Tool Bits . . . Simonds Flat Ground Stock . . . Special Plates . . . Flame Cutting . . . Diamond Broach Hack Saws.

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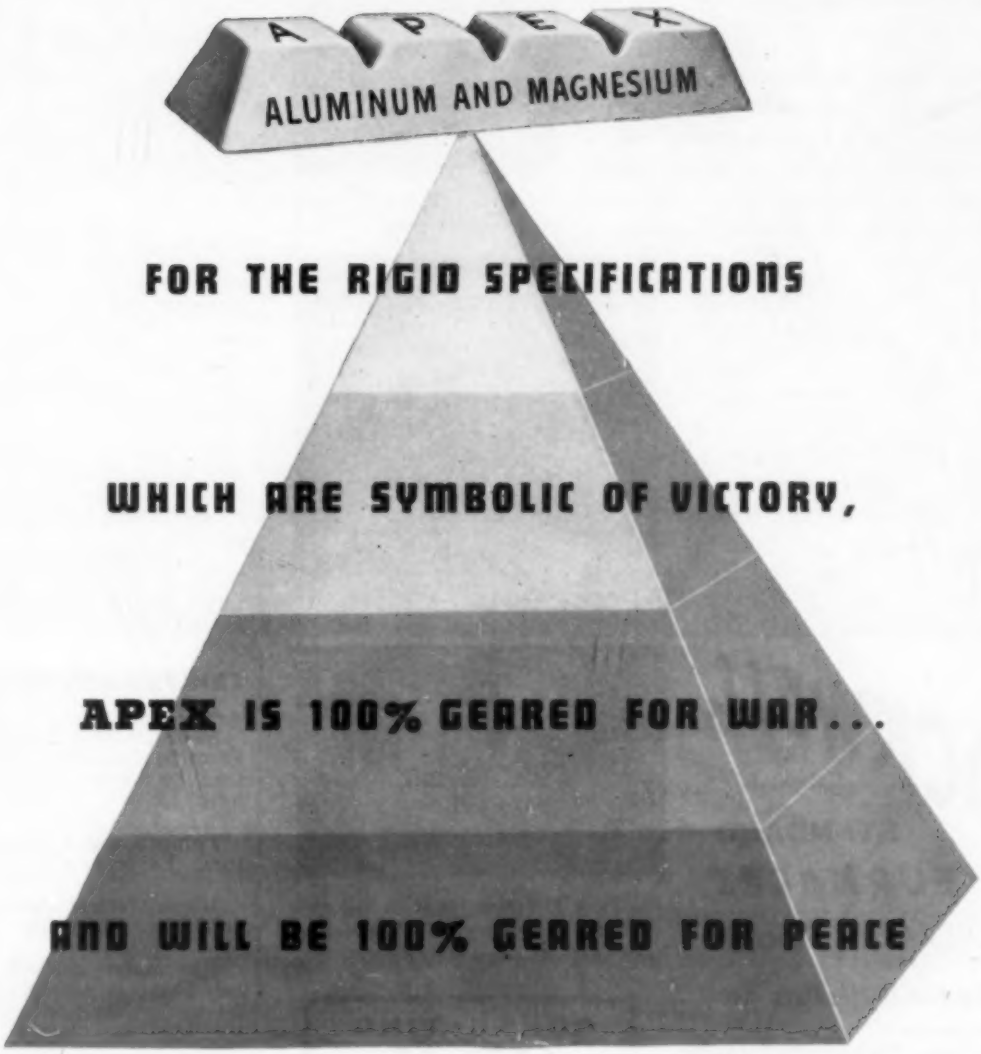
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FOR THE RIGID SPECIFICATIONS
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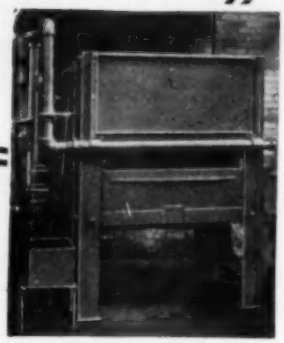
APEX IS 100% GEARED FOR WAR...
AND WILL BE 100% GEARED FOR PEACE

SMELTING

COMPANY

CHICAGO, ILLINOIS

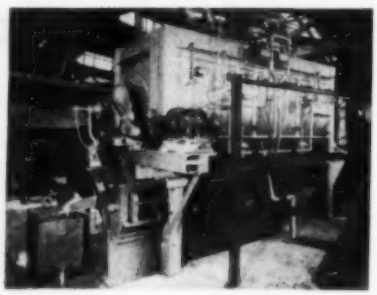
HOW TO MEET YOUR HIGHEST STANDARDS OF HEATING UNIFORMITY



Economizer Forge Furnace, recuperative type.

Let's think in terms of finished product: If you want the kind of heating performance that is reflected in unvarying uniformity of finished product to meet your most rigid quality specifications, then you will be wise to install Rockwell furnaces.

Rockwell furnaces, no matter how large or small, embody the correct combination of efficient fuel utilization and controlled heat application to the work. They are available for any fuel in any capacity to meet your requirements for batch or continuous heat treatment under normal or special atmospheres.



Revolving Retort Heat Treating Furnace, automatic charging and discharging.

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STANDARD FURNACES

Oil • Gas • Electric

Pot Type Furnaces for lead, salt and cyanide hardening, oil tempering, lead and soft metal melting.

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Forging Furnaces
Revolving Retort Carburizing Furnaces
Revolving Retort Heat Treating Furnaces
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Crucible Melting Furnaces
Tilting Reverberatory Furnaces
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Special Batch or Conveyor Furnaces

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In addition to the furnace engineering service, Rockwell offers a complete metallurgical consulting service, involving investigations and recommendations concerning the proper heating and cooling of metal products for uniform results.

W. S. ROCKWELL COMPANY

BATCH TYPE & CONVEYOR FURNACES FOR EVERY HEATING APPLICATION

46 CHURCH STREET NEW YORK 7, N. Y.

WHAT'S NEW

IN MANUFACTURERS' LITERATU

Eberbach micro hardness tester illustrated and described in booklet by Eberbach & Son Co. Bulletin 269.

Moisture determinations of a wi range of materials with new Moistu Teller instrument are described new leaflet by Harry W. Dietert C Bulletin 299.

Stresscoat, a method of analyzi distribution, direction and value local strains. Magnaflux Cor Bulletin 301.

Two new folders describe Searl ray 80, new self-contained X-ray un of North American Philips Co. Bu letin 377.

High intensity industrial illum nator is illustrated and described new leaflet by Kelley-Koett Mfg. C Bulletin 406.

30th Anniversary Catalog show the special metallurgical equipme offered by Claud S. Gordon Co. Bu letin 410.

Laboratory and industrial pH m ters are described and explained leaflet issued by Beckman Instru ments Division. Bulletin 422.

8-page illustrated leaflet describe line of industrial instruments o fered by the Brush Development Co. Bulletin 428.

TEMPERATURE CONTROL

New 29-page catalog — Microma Electric Control — has just been is sued by Leeds & Northrup Co. Bul letin 76.

Potentiometer temperature indica tors. Foxboro Co. Bulletin 82.

Micro-Optical Pyrometers. Pyrom eter Instrument Co. Bulletin 89.

Pyrometer control of high speed salt baths is described in new book let by Brown Instrument Co. Bulle tin 324.

Industrial thermocouples. Arkla S. Richards Co. Bulletin 93.

Pyrometer Controller. Illinois Tes ing Laboratories, Inc. Bulletin 84.

New leaflet describes valve opera tor of industrial operation of valves dampers and other control devices Automatic Temperature Control Co Bulletin 381.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 37 376, 378, 382, 384, 386, 387, 388 and 39

PAGE *Welding* ELECTRODES

PAGE COATING HELPS YOU ON YOUR STAINLESS WELDING

Certainly it is important to you that **PAGE** developed a range of electrodes for welding stainless steel that is complete.

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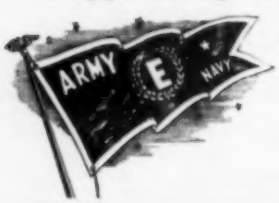
WITH BLAST CLEANING PROBLEMS

ROTOBLAST BARREL

SPECIAL MACHINE

40 years continuous service—growing with the metal processing industries—has brought Pangborn engineers into intimate contact with almost every possible blast cleaning and dust control problem. To this rich background of experience is added more than two years of successful designing, building and erecting of specialized war plant installations — both ROTOBLAST and Air Blast. The Army-Navy "E" award, with added star, proves the value of this equipment in the vital war effort. Qualified beyond question to recommend only the most efficient equipment—Pangborn asks specifically for an opportunity to work with you—at once—on any war or post war blast cleaning or dust control program you now visualize. "Come to Pangborn."



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PANGBORN

WORLD'S LARGEST MANUFACTURER OF DUST COLLECTING AND BLAST CLEANING EQUIPMENT

PANGBORN CORPORATION · HAGERSTOWN, MD.

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

New Pyrometer Accessory Manual gives engineering data on selection and installation of thermocouples. The Bristol Co. Bulletin 421.

16-page booklet describes and illustrates Wheelco Instrument Co. line of measuring and control instruments. Bulletin 425.

HEATING • HEAT TREATMENT

Equipment for determining the quantity of sodium cyanide in molten cyanide mixtures used in heat treatment is described in new bulletin by the Kocour Co. Bulletin 394.

24-page technical data and operating manual covering the Deepfreeze low temperature industrial chilling machines has been issued by Deepfreeze Div., Motor Products Corp. Bulletin 398.

36-page catalog illustrates Kold-Hold line of thermal, sub-zero and stratosphere processing and testing machines. Kold-Hold Mfg. Co. Bulletin 99.

Induction heating. Induction Heating Corp. Bulletin 103.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin 102.

Easy-selection charts on gas-burning equipment. National Machine Works. Bulletin 105.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin 107.

Electric Furnaces. Ajax Electrothermic Corp. Bulletin 106.

Homo method for nitriding is described and illustrated in new 19-page catalog by Leeds & Northrup. Bulletin 100.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin 101.

Centrifugal blowers and exhausters. Roots-Connersville Blower Corp. Bulletin 270.

Furnaces for heat treatment of aluminum, magnesium and their alloys. Lindberg Engineering Co. Bulletin 271.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 372, 374, 378, 382, 384, 386, 387, 388 and 390

SALEM CAN BUILD YOU ANY TYPE OR ANY SIZE OF

INDUSTRIAL FURNACES

● Salem designs heat treating furnaces to provide maximum operating efficiency for your specific manufacturing operations.

We can design and build any size or any type of heat treating furnace, gas, oil, or electric-fired, for either ferrous or non-ferrous material.

On this page we show current examples of Salem equipment, illustrating our scope, versatility, and experience.

When you need heat treating equipment, check the firm which will build the kind of installation you want . . . SALEM ENGINEERING COMPANY.

...ar Furnace for Tubular Products

...orizontal cylindrical furnace affords ex... heating uniformity between 800° F. and ...F. Designed to handle steel pipe, 2 to 10 ... diameter.

World's Largest Rotary Furnace

...Heating Furnace has a capacity of 80,000 pounds per hour at 2250° F. when heating 10" billets on a five hour cycle. Hearth area of 2100 sq. ft. is equipped with a variable speed mechanism which gives range of 2 to 8 hours per revolution.

Salem's Witter Mill

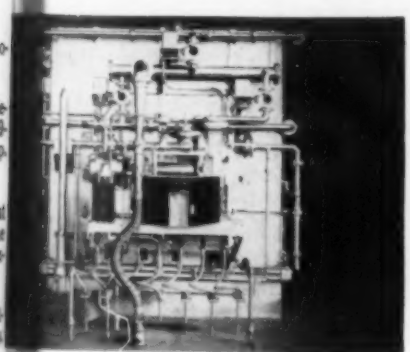
...mill elongates and rolls shells to finished ... dimensions which eliminates much of the ...achining operation, saves material and man ... provides low operating cost, plus min... maintenance. Small floor space required.

Batch Type Furnace

Produces over 30 tons of alloy steel per hour at 2250° F. Handles either ingots, billets, or slabs. Equipped with Salem Needle Metallic Recuperator which preheats either gas or oil for greater combustion efficiency.

Aluminum Annealing Furnace

Each furnace is built to individual customer specifications. In this furnace, a unique method of convection heating is applied for processing aluminum plates and sheets.

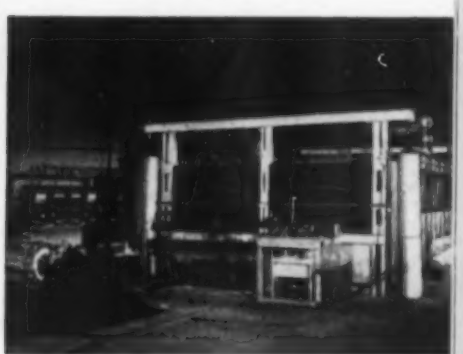


...here Annealing With Direct Firing

...with gas for an operating temperature of 1450° ... capacity of 40,000 pounds of bar stock per ... The heating and cooling cycle is 20 hours.

Circular Soaking Pits

They heat cold or hot carbon or alloy steel ingots 25% faster. Heat is obtained from a multiplicity of oil or gas burners.



Continuous Pusher Type Furnace

Has double chamber—one for hardening small forgings or stampings and one for drawing. Both can be used for normalizing.

SALEM ENGINEERING COMPANY

SALEM ENGINEERING CO. · SALEM, OHIO

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Gas, oil and electric heat treating and carburizing furnaces. Holcroft & Co. Bulletin 114.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin 115.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin 116.

Full muffle and other heat treating furnaces described in catalog by Charles A. Hones, Inc. Bulletin 117.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin 119.

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin 118.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin 120.

Modern electric furnaces for heat treating. Harold E. Trent Co. in new Bulletin 121.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin 122.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin 123.

Tocco hardening, brazing, annealing and heating machines. Ohio Crankshaft Co. Bulletin 124.

Handling cylinder anhydrous ammonia for metal treaters. Armour Ammonia Works. Bulletin 128.

Industrial Furnaces. W. S. Rockwell Co. Bulletin 133.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin 134.

Air-Oil Ratiotrol for proportioning flow of fuel oil and air to oil burners. North American Mfg. Co. Bulletin 135.

Two new bulletins on vertical carburizers and on carbonia finish. American Gas Furnace Co. Bulletin 139.

Van Norman induction heating units. Van Norman Machine Tool Co. Bulletin 144.

Gas-air premix machine. Eclipse Fuel Engineering Co. Bulletin 138.

Controlled atmosphere furnace. Delaware Tool Steel Corp. Bulletin 141.

Dual-Action quenching oil. Gulf Oil Co. Bulletin 132.

Furnaces. Tate-Jones Co. Bulletin 142.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin 143.

Heat treating, brazing and melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin 147.

Vertical Furnace. Sentry Co. Bulletin 148.

Conveyor Furnaces. Electric Furnace Co. Bulletin 149.

High and low temperature direct fired furnaces. R-S Products Corp. Bulletin 146.

New Electric Furnace. American Electric Furnace Co. Bulletin 150.

Electric Furnaces for laboratory and production heat treatment. Hoskins Mfg. Co. Bulletin 152.

Flame-type mouth and taper annealing machine for steel cartridge cases. Morrison Engineering Corp. Bulletin 154.

Dehumidifier. Pittsburgh Lectr dryer Corp. Bulletin 155.

No-Carb, a liquid paint for preve tion of carburization or decarburiz tion. Park Chemical Co. Bulleti 156.

16-page engineering and data boo let on proportioning oil burner Hauck Mfg. Co. Bulletin 160.

Pictorial bulletin describes fu naces for heat treating, normalizin annealing, forging. Vulcan Cor Bulletin 161.

High Temperature Fans. Michia Products Corp. Bulletin 158.

Protective combusted atmosphere in Hevi Duty Electric Co. furnace are discussed in 12-page Bulletin 31

Turbo-Compressor data boo shows how to calculate compresse air systems for a dozen different a plications. Spencer Turbine Co. Bu letin 329.

Catalog of heat treating materials Heatbath Corp. Bulletin 322.

Photographs and drawings a used to describe car type quick anneal oven by Whiting Corp. Bu letin 355.

Standardized sizes of semi-muffl and pot-type furnaces are describe and pictured in new leaflet by Demp sey Industrial Furnace Corp. Bu letin 354.

Use of pulverized coal in the meta lurgical industries, equipment and designs, are described by Amsler Morton Co. in Bulletin 361.

Illustrated bulletin on stress-relieving, car-type furnaces. Radiant Combustion. Bulletin 375.

Furnaces for heat treating tools dies and parts are described in new leaflet by Despatch Oven Co. Bulletin 362.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 372, 374, 376, 382, 384, 386, 387, 388 and 390.

Stuart's Thred Kut SOLVOL "Super-Kool" CODOL

Begin with the finest cutting Fluids...

THEN APPLY THEM PROPERLY . . .

● Anything less than the best cutting fluids available is a handicap to your production. Equally important is *proper application.* Stuart Oil Products and Stuart Oil Engineering will give all the advantages it is possible to get from cutting fluids.

For All Cutting Fluid Problems

D. A. STUART OIL CO.

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Warehouses in Principal Metal Working Centers

Heat treating the wearing face of a coupling by the Lepel High Frequency Induction Heating Process. Toughness and ductility of the balance of the part is unimpaired.

The heart of precise, selective heat treating, the Lepel High Frequency Induction Unit—compact, easily movable, relatively inexpensive. Operated manually or fully automatic.

Produces Better Parts at Lower Cost...

Precise, selective heat treatment, as developed and perfected by Lepel, permits the application of heat up to any selected temperature, *exactly* where it is required and for the *exact* period of time necessary to produce the desired result.

Amazing in its speed, Lepel equipment reduces from minutes to seconds the time required for hardening, annealing, stress relieving and for brazing and soldering—the same unit performing all of these operations. Yet it maintains a degree of precision and uniformity rarely attainable through other methods.

Fully automatic operation is possible, eliminating the human equation and assuring speed, economy, conservation of manpower and critical materials and a minimum of rejections.

Lepel equipment achieves the ultimate in simplicity of operation, dependability and cleanliness. As a result, Lepel installations in many leading war industries are operated entirely by women.

While Lepel equipment has been a boon to wartime production, it is instantly adaptable to peace-time applications without any conversion whatever.

Write or wire for complete information, or, better still, send us samples of your work with specifications for heat treating, brazing or soldering. Our engineers will then perform the work specified and return the samples with specific data, recommendations and cost estimates. This service entails no expense or obligation on your part.

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PIONEERS IN INDUCTION HEATING

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HIGH FREQUENCY INDUCTION UNITS

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Rapid oil coolers and heat transfer equipment are described in new catalog issued by Bell & Gossett Co. Bulletin 365.

New book "Hardness" describes and evaluates hardness research of noted pioneers, methods of testing and testing instruments. Nitralloy Corp. Bulletin 366.

New booklet describes uniform case hardening up to .150" with controlled carburizing baths. American Cyanamid & Chemical Corp. Bulletin 372.

82-page catalog describes in detail General Electric heat treat furnaces. Bulletin 380.

Four basic heat treating atmospheres are described in new booklet by Westinghouse. Bulletin 383.

War Production Data — 30 pages of useful information on metal working, heat treating and other metal producing operations just issued by E. F. Houghton & Co. Bulletin 387.

Laboratory and tool room furnace. Mahr Mfg. Co. in new Bulletin 327.

Carbottom furnaces are illustrated in new leaflet issued by Surface Combustion. Bulletin 416.

Heat Treating Topics" is title of new bulletin of special interest to heat treaters, issued by Rex & Erb. Bulletin 424.

New leaflet pictures many applications of selective heating with salt bath furnaces. Ajax Electric Co. Bulletin 429.

Two new folders describe liquid bath carburizing salts and special purpose salts. G. S. Rogers & Co. Bulletin 431.

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin 162.

Heavy Duty Refractories. Norton Co. Bulletin 164.

Cromox, new protective refracto coating material for prolonging l of firebrick, insulating firebrick, a castable refractories. Federal Refra tories Corp. Bulletin 163.

Super Refractories catalog. Carb rundum Co. Bulletin 165.

Ramix bottom for basic ope hearth furnaces. Basic Refractori Inc. Bulletin 168.

Conductivity and heat transf charts. Johns-Manville. Bulletin 1

Brickseal refractory coating. Brick seal Refractory Co. Bulletin 169.

D-E insulating materials and the application are described in ne data booklet by Armstrong Cork C Bulletin 208.

Zircon refractories in alumino open hearth furnaces. Chas. Tayl Sons Co. Bulletin 347.

H-W magnamix, a Washington ma nesite ramming mixture for ope hearth and electric steel furnace Harbison-Walker Refractories C Bulletin 371.

Charts to simplify solution of hea transfer problems in refractories an high temperature insulation. Alli Lumnite Cement Co. Bulletin 378.

Steel Plant Cement for hot or co patching of soaking pits, open hearths, electric furnaces, forging furnaces and reheating furnaces i described in new folder by Electro Refractories & Alloys Corp. Bulletin 407.

FINISHING • PLATING • CLEANING

Automatic and semi-automatic plat ing equipment for a variety of proc esses and products are illustrated in 40-page booklet issued by Frederic B. Stevens, Inc. Bulletin 397.

Roto-Finish equipment for de burring, buffing, polishing and color ing. Sturgis Products Co. Bulletin 170.

A protective, deep black finish to steel. Heatbath Corp. Bulletin 171.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin 172.

Motor-Generators for electroplat ing and other electrolytic processes Columbia Electric Mfg. Co. Bulletin 173.

MOORE RAPID *Lectromelt* FURNACES

Lectromelts are available in both top charge and door charge types.
Sizes range from 100 tons to 25 pounds capacity.

Pittsburgh Lectromelt Furnace Corp.
PITTSBURGH, PENNSYLVANIA

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Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 372, 374, 376, 378, 384, 386, 387, 388 and 390

ALUMINUM LIVES TO FIGHT AGAIN!

• Rigid are the demands of war production and aluminum's part grows more important with every passing day.

The amazing thing is the way aluminum is being re-enlisted in this war effort.

Take for example, this wrecked plane. The aluminum reborn from its twisted and scarred wreckage is reincarnated into the vital parts of our new modern tanks.

And what's more . . . there are hundreds of other applications for this reborn aluminum. The exactness with which this aluminum can be realloyed to meet the most rigid of wartime specifications is a tribute to American science and ingenuity.

Aluminum alloys, as produced by the members of the Aluminum Research Institute, are being re-enlisted every day . . . living to fight again against our enemy . . . playing an important role in the production program that will help hasten Victory.

Aluminum and Magnesium, Inc.
Sandusky, Ohio

The American Metal Company, Limited
New York City

Apex Smelting Co.
Chicago, Illinois

The Cleveland Electro Metals Co.
Cleveland, Ohio

Federated Metals Division American Smelting and Refining Company
New York City and Branches

General Smelting Company
Philadelphia, Pennsylvania

William F. Jobbins, Inc.
Aurora, Illinois

R. Lavin & Sons, Inc.
Chicago, Illinois

The National Smelting Company
Cleveland, Ohio

Niagara Falls Smelting & Refining Corp.
Buffalo, New York

Sonken-Galamba Corporation
Kansas City, Kansas

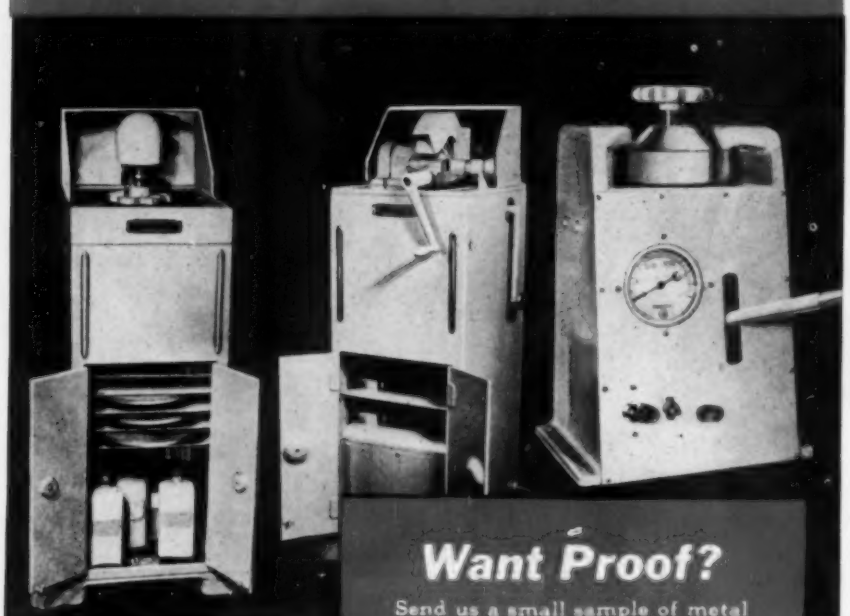
U. S. Reduction Co.
East Chicago, Indiana

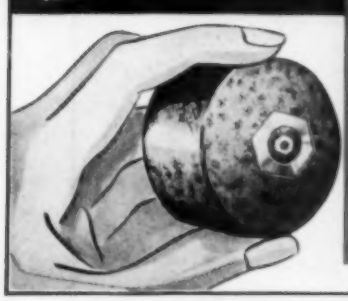
ALUMINUM RESEARCH INSTITUTE

111 West Washington Street, Chicago 2, Illinois

Advanced Technique for preparation of metallurgical specimens!

In one typical installation of "Precision-Jarrett" apparatus for preparing metallurgical specimens, one operator running three machines for cutting, mounting and polishing, is turning out 80 finished specimens per 8 hr. day! Advanced technique is the answer . . .





Want Proof?

Send us a small sample of metal you must polish. We will cut it, mount it in a Bakelite plug, polish it ready for microscopic examination, and send it back to you. You will not be obligated!

Metal specimen embedded in Bakelite plug, ready for microscopic examination. Hydraulic press molds plug in 8 minutes.

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Metallurgical Apparatus *manufactured by*

PRECISION SCIENTIFIC CO.

1750 N. SPRINGFIELD AVENUE, CHICAGO 47, ILL.

Engineers and builders of laboratory equipment

WHAT'S NEW

IN MANUFACTURERS' LITERATU

Pickling. Wm. M. Parkin Co. B letin 174.

Detrex metal cleaning machin metal cleaning chemicals and pr essing equipment. Detrex Corpo tion. Bulletin 175.

Electrochemical Descaling. B lard-Dunn Process Div., Bullard C Bulletin 212.

Airless Rotoblast. Pangborn Co Bulletin 176.

Cadmium Plating. E. I. duP deNemours & Co., Inc. Bulletin 1

Rust inhibiting wax coatings protection of metal. S. C. Johnson Son, Inc. Bulletin 180.

Tumbling and cleaning. Glo Stamping and Machine Co. Bulle 179.

Catalog on finishing and cleani Frederick Gumm Chemical Co., In Bulletin 292.

Resilon corrosion-resistant te linings and applications are d scribed in 8-page leaflet by Unite States Stoneware Co. Bulletin 291.

"Indium and Indium Plating". I dium Corp. of America. Bulletin 1

Service report describes me Oakite machining, drawing, degrea ing and descaling materials. Oaki Products, Inc. Bulletin 210.

Jetal process and its characteri tics as a protective coating. Afro Chemical Co. Bulletin 213.

Catalog section on new sheet Kor seal linings for tanks of welded ste wood or concrete has been issued b the B. F. Goodrich Co. Bulletin 1

Lead plating is discussed in ne booklet issued by Harshaw Chemic Co. Bulletin 109.

Cleaning and finishing machine Howard Engineering & Mfg. Co. B letin 110.

Four types of solvent degrease and cleaners are described in ne leaflet by Technical Processes Di Colonial Alloys Co. Bulletin 230.

Discussion of anodizing, chrom tizing and phosphatizing in illu trated 60-page book has been issue by Turco Products, Inc. Bulletin 2

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 37 374, 376, 378, 382, 386, 387, 388 and 3

Grow 2 Fruits
ON ONE TREE?

It isn't impossible. Burbank did it. And it isn't impossible for Driver-Harris engineers to virtually double the furnace load in heat treatment operations . . . by devising improved load fixtures.

Here is one of many examples

This conventional nest of trays could handle only 48 gears. The aircraft engine manufacturer asked if D-H could increase the capacity within the same shell.

D-H specialists designed and cast this multiple spider fixture—and increased loading capacity to 84. Also, the D-H fixture makes loading from the side a simple matter.

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

112-page **manual describes Chemicals by Glyco. Glyco Products Co. Bulletin 346.**

Cleaning castings **and forgings at low cost by tumbling is described in leaflet by Whiting Corp. Bulletin 356.**

Illustrated booklet **describes blast cleaning equipment offered by Ruemelin Mfg. Co. Bulletin 360.**

Tumbl-Spray metal washing machine is described in new leaflet issued by American Foundry Equipment Co. Bulletin 413.

Modern polishing wheel weights to give a polishing wheel perfect balance are described by the Manderscheid Co. in Bulletin 417.

Metal cleaning solutions for various metals are described in leaflet issued by the DuBois Co. Bulletin 419.

Three new booklets have been issued by the Enthone Co. describing an acid addition agent, hard drying rust-inhibiting waxes and a new alkali steel cleaner. Bulletin 420.

Special data sheets on compounds for various cleaning jobs are offered by MacDermid, Inc. Bulletin 436.

Technical bulletin describes materials developed to meet specialized processing and cleaning needs. Kelite Products, Inc. Bulletin 438.

New 1944 catalog describes metal cleaning equipment offered by N. Ransohoff, Inc. Bulletin 439.

ENGINEERING • APPLICATIONS • PARTS

New 32-page illustrated booklet contains much data on manganese steel for the railroad industry. American Manganese Steel Div. Bulletin 388.

Illustrated leaflet presents data and uses of special alloys resisting corrosion, high temperatures and abrasion. The Duraloy Co. Bulletin 390.

Catalog **gives complete specification data on Bunting bearings and bars. Bunting Brass & Bronze Co. Bulletin 343.**

Heat treating fixtures **for pit-type furnaces are shown in new booklet by Driver-Harris Co. Bulletin 363.**

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 372, 374, 376, 378, 382, 384, 387, 388 and 390.

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Pressed steel pots are described by Bell & Gossett Co. in new Bulletin 364.

Carburizing Boxes. Pressed Steel Co. Bulletin 193.

54-page booklet, "File 41—Engineering Data Sheets", gives complete facts on Ampco Metal's physical properties and service record. Bulletin 368.

New information sheets on tapered and formed tubes have just been issued by Summerill Tubing Co. Bulletin 369.

Chace manganese alloy No. 772 in sheets, strips, rod and special shapes described by W. M. Chace Co. Bulletin 190.

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin 192.

Meehanite Castings. Meehanite Research Institute. Bulletin 196.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin 197.

Steel Castings. Chicago Steel Foundry Co. Bulletin 199.

Heat Resisting Alloys. General Alloys Co. Bulletin 200.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin 201.

Bimetals and Electrical Contacts. H. A. Wilson Company. Bulletin 202.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin 203.

Industrial baskets, crates, trays and fixtures. Rolock, Inc. Bulletin 204.

Cooper standard alloys. Cooper Alloy Foundry Co. Bulletin 206.

Many applications and savings through use of drop forgings are shown in Drop Forging Topics, issued by Drop Forging Assn. Bulletin 240.

24-page catalog is guide to properties and use of Monsanto plastics. Monsanto Chemical Co. Bulletin 319.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 372, 374, 376, 378, 382, 384, 386, 388 and 390.

REINHOLD BOOKS
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METALS and ALLOYS DATA BOOK—*By Samuel L. Hoyt.* Here—between two covers—are the records of *all* metal properties. 340 tables of engineering property data on both common and rare metals and alloys. Specially arranged for easy reference, with indexes, by subject and alphabetical. A book to USE . . . not a thesis.
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TUNGSTEN—Its History, Geology, Ore-Dressing, Metallurgy, Chemistry, Analysis, Applications and Economics. *By K. C. Li and Chung Yu Wang.* Meets the need for a comprehensive treatment of the geology, processing and uses of this strategic metal. The occurrence, composition and preparation of tungsten ores; its uses, chemistry and economic aspects—all are discussed. Includes maps, illustrations, color reproductions. Authoritative, up-to-the-minute.
325 Pages—A.C.S. Monograph No. 94—$7.00

BERYLLIUM—Its Production and Application. *By Zentralstelle für Wissenschaftliche-Technische Forschungsarbeiten des Siemens-Konzern. Translated by Richard Rimbach and A. J. Michel.* Only book in English on beryllium. Articles by leading specialists on analytical chemistry of beryllium, its thermal reduction, production, production of alloys by electrolysis, theory, properties and effects of age-hardening, conductivity, density, etc. 198 diagrams and photomicrographs.
331 Pages—Illustrated—$10.00

A COURSE IN POWDER METALLURGY—*By Walter J. Baeza.* Production of metal powders; specifications; classification of particle size; cohesion; manufacturing problems; experiments, precautions, results. Indexed.
212 Pages—Illustrated—$3.50

SHEET STEEL and TIN PLATE—*By R. W. Shannon.* Complete presentation of industrial iron production in general and sheet steel and tin plate in particular. Describes industrial processes, various refining processes, application, uses, grades and finishes, with voluminous notes, appendices, bibliography and index.
285 Pages—Illustrated—69 Figures—$2.50

ALUMINUM PAINT AND POWDER—*By J. D. Edwards.* Comprehensive, concise, authoritative coverage of these important substances. Manufacture of aluminum powder; its properties; composition of aluminum paint; uses. With appendix and indexes, alphabetical and by subject.
216 Pages—78 Illustrations—$4.50

CONDENSED CHEMICAL DICTIONARY—Third Edition (1942). Compiled and Edited by the Editorial Staff of the Chemical Engineering Catalog. Francis M. Turner, Editorial Director. Thomas C. Gregory, Editor.
Unrivalled in completeness. Important, up-to-date information on chemical and metallurgical substances not available elsewhere in book form.
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SILVER IN INDUSTRY—*By L. Addicks.* Sponsored by the government's Silver Research Project and many important firms in the field, contains articles by recognized experts. Alloys; bonding; coatings; contacts; resistance; catalytic effects; statistics of consumption; summary; conclusions, appendices, bibliography and indexes.
636 Pages—Profusely Illustrated—$10.00

SAMPLING AND ANALYSIS OF CARBON AND ALLOY STEELS—Prepared by the Chemists' Committee of the Subsidiary Companies of the U. S. Steel Corporation. Includes approved procedures for sampling mill products, and for determining all the elements that may occur in steel under any conditions of combination.
356 Pages—20 Figures—$4.50

CORROSION RESISTANCE OF METALS AND ALLOYS—*By R. J. McKay and R. Worthington.* Exhaustive study of every known form of corrosion from every source. Bibliography. Indexed by author and subject.
492 Pages—A.C.S. Monograph No. 71—66 Figures—313 Tables—$7.00

PROTECTIVE COATINGS FOR METALS—*By R. M. Burns and A. E. Schuh.* This important and far-reaching subject is so comprehensively covered that this book forms a reference work invaluable to anyone in the metallurgical field.
407 Pages—89 Figures—A.C.S. Monograph No. 79—$6.50

TIN, ITS MINING, PRODUCTION, TECHNOLOGY AND APPLICATIONS—*By C. L. Mantell.* Its properties, production, distribution, and consumption: alloys, compounds, corrosion. Indexed.
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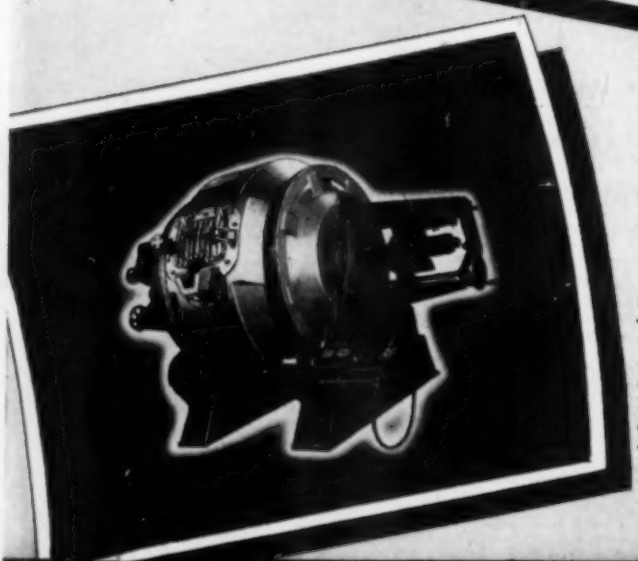

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WHAT'S NEW
IN MANUFACTURERS' LITERATURE

Alloy Castings. Ohio Steel Foundry Co. Bulletin 207.

Details of new Chemicast process for small brass parts will be supplied by Chemicast Div., Whip-Mix Corp. Bulletin 330.

Reference data book entitled "The Improvement of Metals by Forging" has been issued by Steel Improvement & Forge Co. Bulletin 409.

16-page catalog illustrates wide variety of welded steel crates and baskets for pickling, enameling and heat treating operations. Youngstown Welding and Engineering Co. Bulletin 423.

Industrial applications of National and Karbate carbon and graphite products are illustrated in 16-page booklet issued by Natonal Carbon Co., Inc. Bulletin 426.

Attractive, illustrated data book shows many applications of metal spinning by Milwaukee Metal Spinning Co. Bulletin 427.

Illustrated leaflet describes stainless steel castings by Atlas Foundry Co. Bulletin 437.

MELTING • CASTING • MILL OPERATIONS

52-page booklet describes Moore rapid Lectromelt furnaces for iron, steel, nickel and copper melting and refining. Pittsburgh Lectromelt Furnace Corp. Bulletin 404.

Cradle furnace which produces a homogeneous gray iron of uniform chemical analysis, uniform temperature and controlled carbon content is described by Whiting Corp. Bulletin 357.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin 186.

Interesting and helpful information available on the use of alloy pots for heating operation by the Swedish Crucible Steel Co. Bulletin 137.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.

Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 372, 374, 376, 378, 382, 384, 386, 387 and 390.

DURIMET is the copyrighted trade name for a family of corrosion-resistant alloys made only by The Duriron Company, Inc.

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New Method Replaces Forging and Fabricating in Many Cases

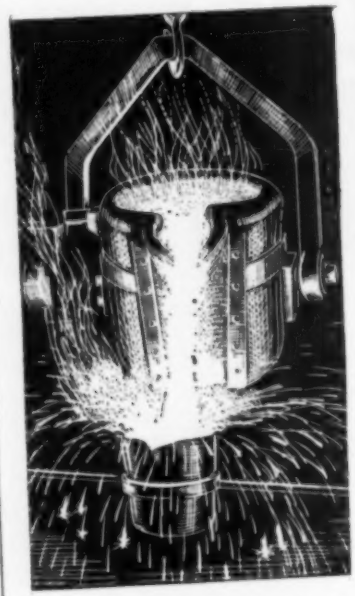
HILLSIDE, N. J.—A new method of casting stainless steel centrifugally has recently been developed by The Cooper Alloy Foundry Co. of this city. According to company spokesmen, parts formerly forged or fabricated can now be cast successfully—with resultant savings in cost, man-hours and delivery time.

Cooper has already demonstrated the ability of his new process to crack critical bottlenecks in the manufacture of mass-produced equipment for airplanes. Many such parts are now produced in record time.

Centrifugal casting of stainless steel, however, provides industry with much more than a new way to speed vital war production. It means that either the static or the new centrifugal method can be used —whichever is better, or more economical, or faster.

The Cooper Alloy Foundry Co., where the new process was developed, has specialized in the production of stainless steel, monel, nickel, chrome iron, chrome nickel and other alloy castings since 1922. It offers users of corrosion, heat and abrasion castings a complete alloy casting service—including practical assistance in the selection of alloys.

Concerns interested in the possibilities of this new process are invited by the company to submit descriptions



(with sketches) of the castings, fabricated parts or forgings they now use, together with notes on any special requirements. Company engineers will then make recommendations. Users will not be obligated in any way in taking advantage of this service.

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WHAT'S NEW
IN MANUFACTURERS' LITERATU

Crucibles for brass, copper, alu num and magnesium industri Electro Refractories and Alloys Co Bulletin 183.

Ingot Production. Gathmann En neering Co. Bulletin 185.

Manganese-Titanium Steels. Ti nium Alloy Mfg. Co. Bulletin 184.

Electric Furnaces. Detroit Electr Furnace Div., Kuhlman Electric C Bulletin 189.

Operating Features, capaciti charging methods of the Hero electric furnace. American Brid Co. Bulletin 215.

Chart for the correction of brass for zinc loss should interest foundr men. Foundry Services, Inc. B letin 217.

Coke oven plant construction an development in 1942 is describ and illustrated in 12-page pamphl by the Koppers Co. Bulletin 232.

"Fisher Magnesium Scrapbook" Fisher Furnace Co. Bulletin 281.

Attractive booklet describe growth, facilities and offers valuabl alloy hints. Niagara Falls Smeltin & Refining Corp. Bulletin 246.

Vertical centrifugal casting ma chine for production of ferrous an nonferrous castings is described b Centrifugal Casting Machine Co. i Bulletin 315.

Interesting, descriptive leaflet o metal reclaiming mill offered b Dreisbach Engineering Corp. Bull tin 284.

GENERAL

Available material of the U.S. Arm Air Forces is shown in catalog issue by 830th Army Air Force Specialize Depot. Bulletin 401.

New leaflet describes interoffic communication system offered b Executone Communication System Bulletin 385.

Use Handy Coupon on Page 362 for Ordering Helpful Literature.
Other Manufacturers' Literature Listed on Pages 362, 364, 366, 368, 370, 37 374, 376, 378, 382, 384, 386, 387 and 38